The Effect of Time Zone Disparity on the Performance of Dispersed Innovation Teams in the Australian Biotechnology Industry

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed. I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

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List of Abbreviations

B	Beta
BD	Business development
CRO	Contract research organisation
CSL	Commonwealth Serum Laboratories
CSV	Comma-separated values
df	Degrees of freedom
EU	European Union
F	F value
min:sec	Minute:second
N/A	Not applicable
NSW	New South Wales
Qld	Queensland
R^2	Coefficient of determination
R & D	Research and Development
SA	South Australia
Sig.	Significance
SPSS	Statistical Package for the Social Sciences
t	*t*-value
US	United States (of America)
UT	Universal Time
Vic	Victoria
VIF	Variance inflation factor
WA	Western Australia

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Summary

This study aims to assess the impact of time zone disparity on the performance of global innovation teams. The overarching research question addressed in this thesis is *'What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?'*

The Australian biotechnology sector is used as a setting, as this sector typically relies on overseas collaborations that are time zone discordant. Using theories from international business, innovation management, and chronobiology, a theoretical framework is developed that links physical gaps, cultural gaps, language gaps and time zone disparities with innovation success. More importantly, the conditions under the control of management that mitigate the negative effects or amplify the positive effects of working across multiple time zones are identified and included in the theorisation.

Several research aims were identified: firstly, a literature review which brought together a variety of research streams from different disciplines and combine them into a cohesive whole, with the study being informed by prior research in the fields of innovation management, virtual team management, organisational psychology, chronobiology (the underlying biological mechanism of the circadian rhythm), and performance. The second research aim was to construct a conceptual framework with the effect of time zone disparity on team performance, based on the four gaps identified in the research question (temporal, physical, cultural and language), and the actions team members take to mitigate the potentially negative effects of these gaps. The third research aim was to conduct a series of interviews to obtain qualitative data. This data would be used to obtain themes that could then be further examined in the quantitative online survey. The fourth research aim was to

conduct an online survey to obtain quantitative data, measuring the effect of the various issues that had been raised in the interviews, as well as the impact of the mitigating behaviours reported by the interview subjects. Finally, the fifth research aim was to synthesise the qualitative and quantitative data to bring together the findings of the research and formulate a cohesive and coherent narrative into the effects of time zone disparity on the performance of globally dispersed innovation teams.

Because of the research aims, this study took a mixed method approach, in which a series of interviews were followed by an online survey with a larger number of participants. Data collection began with a series of 28 exploratory interviews completed to validate and enrich the framework, followed by an online survey among 153 informants in this sector. It is anticipated that by testing the framework and analysing the data we can bring greater understanding of the effects of time zone disparity within teams, while controlling for other factors that can also affect innovation performance.

Firstly, the results of the study highlight a strong sense of isolation and exhaustion in the cohort, as many subjects studied struggled with the physical challenges of working across multiple time zones. Secondly, there were several temporal organisational approaches to staff working in teams that spanned multiple time zones, and there was generally a distinct lack of organisational input in terms of employees' welfare, and the data presents a solid opportunity for positive organisational input in terms of team performance.

In terms of contribution to theory, it is expected that the results of this study will contribute to understanding the effects of time zone disparity on dispersed team performance and suggest a conceptual model for time zone disparity and performance. This conceptual model has several components that, with impact-mitigating behaviours, ultimately influence performance. The contribution to theory also focuses on global innovation teams including business travellers. Most travel and jet lag research has been conducted in either healthy volunteers or athletes, who have different needs to business travellers in terms of cognitive function versus physical performance (Czeisler & Fryer 2006), and this is particularly important in the Australian context, where often business travellers are isolated from other global innovation team members by the 'tyranny of distance' (Blainey 1966; Gilding 2008).

In terms of contributions to practice, this study could provide possible directions for the management of teams that work across multiple time zones, including the development of guidelines for managing teams that are dispersed across multiple time zones to enhance the team's performance.

The limitations of this study were that firstly, the study subjects were all taken from one nation, Australia. Australian subjects typically partner with more distant nations and travel longer distances than their American or European counterparts, so the impact of time zone differences and jet lag may also be greater. Secondly, the study participants were all from a single industry, the biotechnology sector. Lastly, there was a degree of gender imbalance in the interview phase of the data, with only one third of the interview subjects being female.

Future research on the effect of time zone differences and jet lag on globally dispersed innovation teams could readily examine other industries that also have teams that span multiple time zones globally, such as information technology and banking. Similarly, while the Australian context was particularly fruitful in terms of locating team members working in globally dispersed teams, surveying team members based in other nations may provide an international context for this research. Finally, the effect of flying business class versus economy class can be developed further, as there are very few studies examining the suggested benefit of flying in business class from a performance perspective.

Key words: time zones, innovation performance, dispersed teams, cultural distance, physical distance, biotechnology

1. Introduction

1.1 Introduction

The focus of this thesis is the effect of time zone difference on the performance of globally dispersed innovation teams. 'Today, business is largely a global business, and firms active on this scale must develop new products for global markets' (Salomo, Keinschmidt & De Brentani 2010). New innovations are, by necessity, global in nature, and are driven by globally dispersed teams; teams working on innovative products are typically dispersed globally, and the more successful innovation strategies are more likely to be global ones (Cano-Kollmann, Hannigan & Mudambi 2018; Doz, Santos & Williamson 2004; Eppinger & Chitkara 2006), and innovation activities are frequently offshored (Lewin, Massini & Peeters 2009; Manning, Massini & Lewin 2008), with a positive impact on firm performance (Rosenbusch *et al.* 2019), allowing for specialisation (Arkolakis *et al.* 2018) even with high levels of inter-organizational physical distance (Chen & Lin 2018). Geographical team dispersion has increased in recent years in varied industries as information technology and biotechnology (Gilding 2008; Kumar 2006; Smith & Blanck 2002). One driver of this increased offshoring is the availability of science and engineering talent in emerging economies compared with the difficulties of finding such talent locally in advanced economies (Manning, Massini & Lewin 2008).

This geographical dispersion may have a number of negative effects on innovation (Gibson & Gibbs 2006; Hoegl, Ernst & Proserpio 2007; McDonough, Kahnb & Barczaka 2001), with geographic dispersion having an 'inverted U-shape' relationship to the quality of research and development (R & D) innovation; a limited amount of dispersion improves quality, but a large amount of dispersion greatly diminishes it (Lahiri 2010). Although there is a limited amount of information in the academic literature regarding the performance of dispersed teams in comparison with collocated or local teams, it is known that the management of temporally dispersed teams is more difficult (Espinosa, Nan & Carmel 2015; Lurey & Raisinghani 2001; Magni *et al.* 2013), with time zone differences, culture and language all being barriers to performance (Ferreira, de Lima & da Costa 2012; Nguyen-Duc, Cruzes & Conradi 2015). Time zone differences can lead to extended work days to communicate with team members in other time zones. Also, globally dispersed teams can result different situations to collocated teams, such as collaborating with people but never meeting them face-to-face, working with team members with different languages or cultural backgrounds, working while travelling, and relying heavily on internet-based conferencing applications for communication within the team (Chudoba *et al.* 2005); and isolation and team dynamics can have an impact on performance (O'Leary & Cummings 2007). The configuration of the dispersed team also potentially has a negative impact on performance, with 'social categorisation in teams with geographically based subgroups' (that is, multiple team members at one geographical site) weakening team cohesion (O'Leary & Mortensen 2010), and configuration of innovation teams can have a significant effect on performance (Kafouros *et al.* 2018). However, time zone disparity also offers benefits, such as the ability to work 24-hour days in a 'follow-the-sun' model of workflow, which is used successfully in some sectors, such as information technology (Carmel, Espinosa & Dubinsky 2010; Espinosa & Carmel 2003; Ferreira, de Lima & da Costa 2012; Siebdrat, Hoegl & Ernst 2009).

Studies examining the effect of time zone disparity on team performance have found it to be an obstacle to their success (Lurey & Raisinghani 2001; Nurmi 2011), showing up in such diverse areas including sports, such as baseball (Recht, Lew & Schwartz 1995; Song, Severini & Allada 2017; Waterhouse, Reilly & Edwards 2004; Youngstedt & O'Connor 1999), basketball (Nutting & Price 2017; Roy & Forest 2017), football (Jehue, Street & Huizenga 1993; Lastella, Roach & Sargent 2018; Reilly *et al.* 2007; Smith, Guilleminault & Efron 1997), martial arts

(Peacock *et al.* 2019), rowing (Kölling *et al.* 2017), rugby (Marrier *et al.* 2018), sledding (Bullock *et al.* 2007), sprinting (Aygin, Ceylan & Günay 2018) and volleyball (Chapman *et al.* 2012), and can affect Olympic athletes (Silva, Paiva & Silva 2019). This time zone disparity has also affected Russian athletes moving from the west to the far east of the country to train for the Olympics in Tokyo and Beijing (Palchikova, Dobrovolskiy & Mezentsev 2018). This time zone disparity can also impede global software development (Nguyen-Duc, Cruzes & Conradi 2015) and international banking (Wójcik 2010).

Recently the advent of communication technology has transformed the ability to conduct business internationally, and in terms of modifying performance, team processes and relationships have been found to be stronger predictors of effective performance than the use of advanced communication technology (Hambley, O'Neill & Kline 2007; Lurey & Raisinghani 2001). Despite the development of communication technology, globally dispersed teams still have challenges with communication (Yang *et al.* 2015), and a measure of virtual teams is a dependence on electronic communication (Gibson & Gibbs 2006), which in turn hinders innovation.

Time zone disparity has been show to lead to lower trade in goods across countries (Egger & Larch 2013; Stein & Daude 2007), although this effect is less pronounced in service markets (Head, Mayer & Ries 2009; Kikuchi & Iwasa 2010; Marjit 2007). In this study, it is argued that the effects of time zone disparity on dispersed innovation team performance are poorly understood, not straightforward and warrant closer examination.

One of the key issues working with globally dispersed teams is international travel, and the resultant jet lag. Jet lag's negative effect on performance is often overlooked, with executives 'conducting business in a cloud of caffeinated jet lag' in a 'social culture [that] glorifies sleeplessness' (Czeisler & Fryer 2006), and impaired cognitive function, alertness, and performance as a result of jet lag have been documented in a number of studies (DeFrank, Konopaske & Ivancevich 2000; Rogers & Reilly 2002; Rogers & Reilly 2000), although crossing multiple time zones is only one component of the stress of business travel (Striker *et al.* 1999). Not all factors affecting team performance are understood, with some factors less clear in terms of impact on team performance (O'Leary & Cummings 2007). Time zone differences, in particular, while recognised as a factor of virtuality in dispersed teams (Chudoba *et al.* 2005), have not been completely studied as a standalone factor alone in the innovation management context.

1.2 Research Background

As the globalisation of innovation has increased (Kafouros *et al.* 2008), there has been an increase in the use of virtual teams (Gilson *et al.* 2015) which are geographically and temporally dispersed (Chudoba *et al.* 2005). In virtual teams, face-to-face meetings are important for team cohesion and direction (Siebdrat, Hoegl & Ernst 2009), resulting in a group who travel frequently long distances across multiple time zones. While there is a great deal of research into the management of virtual teams, there is limited research on the team members who travel, despite business travellers being an important resource for companies (Welch, Welch & Worm 2007).

In terms of international travel, there has been a substantial amount of research on the effect of time zone differences with a focus on jet lag (Cingi, Emre & Muluk 2018; Eastman & Burgess 2009; Sack 2010; Zee & Goldstein 2010), but most of the studies have been conducted in either healthy volunteers or in athletes (see Table 1), despite business travellers making a substantial contribution to airlines' income (Gillen & Lall 2004).

In summary, while there is a great deal of literature around virtual teams, there is a limited amount of research on the effect of time zone differences, particularly for those members of virtual teams who travel. There is also a lack of research exploring the effect of jet lag on business travellers, despite business travellers comprising a substantial proportion of flyers.

The research context of the study is now discussed.

1.3 Research Context

The context for this research is the Australian biotechnology industry. Biotechnology is defined as 'any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use' (UN Convention on Biological Diversity 1992), and embraces a variety of disciplines such as medicines, devices, agriculture and waste disposal that involves life sciences (OECD 2001). Financially, the biotechnology sector is major, with a market capitalisation of close to US $1 trillion annually (Ernst & Young 2017, p. 32).

The biotechnology sector is heavily dependent on innovation (Hall & Bagchi-Sen 2002), with performance strongly linked to innovation (Chatterji 2009; Pullen *et al.* 2012; Vanclay, Russell & Kimber 2013; Wu 2013). This innovation is globalised (Athukorala & Kohpaiboon 2010; Cooke 2005), with connections that are especially strong between major research hubs (Hegde & Hicks 2008; Siedschlag *et al.* 2013).

Biotechnology has several clusters which are defined as 'geographic concentrations of interconnected companies and institutions in a particular field' (Porter 1998). These clusters offer benefit to companies established there (Breitzman & Thomas 2015), and Australia, particularly the city of Melbourne, is a major global biotechnology cluster (Gilding 2008; Summerfield 2017). While Australia is a substantial biotechnology hub, it is isolated from the other biotechnology hubs in the United States, Canada and Europe (Ernst & Young 2015) by 'the tyranny of distance' (Gilding 2008). This distance is not only physical as measured in kilometres, but also temporal as measured by time zone differences. The Australian biotechnology industry, with its heavy reliance on overseas partnerships (Gilding 2008) and temporal isolation from them makes an ideal context to discuss the potential impact on performance from time zone disparity within the innovation teams. This thesis now turns to the research question of the study.

1.4 Research Question

Having noted that temporal distance, as measured by time zone differences, has not been studied as an isolated factor in dispersed team management, the research question that is addressed by this study is:

- *What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?*

The remainder of the literature review will discuss previous research on time zone disparity and the performance of geographically dispersed innovation teams.

1.5 Research Aims

1.5.1 Research Aim 1: Literature Review

The research question addressed in this thesis is *'What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?'* In order to address the various elements of the research question, five streams of research were individually examined in a literature review and then the streams were combined to form a cohesive whole: innovation management, virtual team management, organisational psychology, chronobiology (the underlying biological mechanism of the circadian rhythm), and performance to give insight to the effect of time zone disparity on dispersed global teams.

Firstly, the ‘global innovation context’ phrase from the research question requires the examination of the innovation process, particularly for innovation that is globalised, as innovation increasingly links teams in distant places (Binz & Truffer 2017). Virtual team management, with particular focus on time zone disparity and temporal distance within virtual teams is explored to address the ‘dispersed teams’ in the research question. Innovation has become increasingly globalised, leading to the rise of virtual teams (Harvey & Griffith 2007), and time zone disparity is one of the key issues in managing virtual teams (Espinosa, Nan & Carmel 2015). Organisational psychology is then examined, with a discussion around long hours, travel, and the support that companies offer (or fail to offer) their employees who travel across multiple time zones (Ivancevich, Konopaske & Defrank 2003). The effect of travelling across multiple time zones is in the field of chronobiology, the biological aspects of the human circadian rhythm (and therefore jet lag), and the potential detrimental effects of jet lag on innovation team performance. Finally, the performance component of the research question is addressed, with the various levels of performance, individual, team and firm each examined.

Therefore, the first research aim is to conduct a literature review that integrates insights on the five areas of innovation, virtual teams, organisational psychology, chronobiology and performance.

1.5.2 Research Aim 2: Conceptual Framework

The second research aim is to develop a conceptual framework around the effect of time zone disparity on team performance. As stated in section 1.4, the research question addressed in the thesis is '*What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?*' The conceptual framework is based on the nature of the gaps within globally dispersed innovation teams, namely, the temporal, physical, cultural and language gaps that potentially disrupt the productivity of these innovation teams, which were used as research constructs. From this conceptual framework several independent variables could be derived, with different types of performance (financial, technological and physical) being taken as dependent variables. Key variables used within the study were the stage of development of the project, the average team size, team duration, as well as physical and cultural distances.

The temporal gaps or temporal distance, measured in terms of the time zone differences within the teams, and their effects on the productivity of these teams (Kanthak & Hertel 2016) is the primary focus of this study. However, the other gaps listed in the research question, namely the physical gaps in terms of distance measured in kilometres (Siebdrat, Hoegl & Ernst 2013), cultural gaps (Muethel & Hoegl 2010) and language gaps (Ferreira, de Lima & da Costa 2012) have also been considered. Additionally, actions taken by team members to mitigate the impact of these gaps on performance were also considered.

1.5.3 Research Aim 3: Synthesis of Qualitative and Quantitative Results

The third and final research aim of this study is to combine the qualitative and quantitative data from the two phases of the study, the interview series and the online survey, combining 'the power of stories and the power of numbers' (Pluye & Hong 2014) to combine the strengths of both methods of research (Hussein 2009). This study used the mixed method approach to allow initial findings to be explored further and generalised to a larger population (Creswell & Plano Clark 2011, pp. 9-10), using the quantitatively measured data to be supported with a narrative from the qualitative data. The results of this synthesis are discussed in detail in section 8.6.

An overview of the methodology and research design is now outlined.

1.6 Methodology and Research Design Overview

1.6.1 Overview

The methodology used in this study is a mixed method approach, with an initial qualitative phase of twenty-eight (28) interviews to look for significant issues, followed by a quantitative survey with over 150 informants. Open questions were used to elicit understandings and explore the interviewees' perspectives (Quinlan 2011, p. 293), with interviews of 30 to 60 minutes in duration (Hackley 2003, p. 119). The intention of the qualitative phase of the study was to generate themes for further evaluation in the quantitative phase of the study (Corbin & Strauss 2008, pp. 156-7).

Themes from the qualitative phase of the study have been identified by the informants for further quantitative analysis. These themes have directed the questions in the quantitative survey currently taking place in the second half of the study. The methodology of this study is discussed further in more detail in chapter 5.

1.6.2 Theoretical Significance

This study aims to contribute to the academic literature in understanding the effect of time zone differences on the performance of global innovation teams.

Firstly, this research constructs a conceptual framework around the different types of distance within global innovation teams, and how the team members offset the negative effects of working across these various distance, with a focus on temporal distance. Temporal distance within teams can have a negative effect on performance (Espinosa, Nan & Carmel 2015; Tzabbar & Vestal 2015), but this temporal distance can also be used to advantage using a ‘follow the sun’ workflow (Carmel, Espinosa & Dubinsky 2010; Manning, Larsen & Bharati 2015).

Secondly, this study aims to identify and assess the effectiveness of a variety of management approaches to innovation teams working across multiple time zones. In the interview phase of the study, the various management approaches were identified and labelled ‘*laissez-faire*’, ‘concentrate the pain’ and ‘set the boundaries’. The effectiveness of these approaches is then ascertained with regressional analysis (Bryman & Bell 2011, pp. 362-82; O'Shannassy & Leenders 2016), after ascertaining variables from the questions (see section 1.7).

Thirdly, in terms of jet lag and business travellers, there is a limited amount of research in the literature (refer to Table 1). The needs of business travellers are quite distinct from those of leisure travellers or athletes, and research specifically for business travellers would address a paucity of data (Baker & Ciuk 2015; Black & Jamieson 2007; Czeisler & Fryer 2006; Welch, Welch & Worm 2007).

Finally, this research combines a variety of disciplines: innovation management, virtual team management, organisational psychology, chronobiology, and performance management. Chronobiology, a branch of biology examining the human circadian rhythm, is a field of study that has not typically been examined in combination with management studies, despite the needs of business travellers who travel frequently (Baker & Ciuk 2015; Black & Jamieson 2007;

Czeisler & Fryer 2006; Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007). This study incorporates a life science component in management research and brings literature from the scientific literature to the field of management.

1.6.3 Practical Significance

The key practical outcome of this study that is anticipated is a set of guidelines for the management of teams with team members who travel internationally on a regular basis. While some international travel is necessary, as face-to-face meetings are vital (Siebdrat, Hoegl & Ernst 2009), the value and role of international frequent travellers is greatly underrated and unappreciated (Welch, Welch & Worm 2007). The lack of active intervention by organisations for the members of globally dispersed innovation teams who frequently travel internationally across multiple time zones points to a duty of care for staff who frequently travel (Black & Jamieson 2007), and the guidelines developed from the findings of this study could improve the performance of these team members.

1.7 Definition of Key Study Variables and Research Constructs

1.7.1 Overview

The variables were developed from similar survey questions, with the survey questions in turn derived from material communicated in the interviews, supplemented with the relevant academic literature. The literature was consulted in several fields, including geographical, cultural and language differences within the team (Chudoba *et al.* 2005; Tomasik 2013), organisational culture (Brett & Stroh 2003), team dynamics (Chudoba *et al.* 2005), team dispersion and communication (Chudoba *et al.* 2005), treatments for jet lag (Arendt 2009; Beaumont *et al.* 2004; Herxheimer & Waterhouse 2003; Lemmer *et al.* 2002; Revell & Eastman 2005; Sack 2010; Waterhouse *et al.* 2007), work-life balance and stress (Harrington 2001;

Westman & Etzion 2002), and the experience of jet lag for team members (Becker, Penzel & Fietze 2015b; Czeisler & Fryer 2006; Herxheimer & Petrie 2002; Sack 2010; Spitzer *et al.* 1999; Waterhouse *et al.* 2007).

For a detailed list of the references used, the questions they generated, and the variables that were derived from these, refer to chapter 5, sections 5.9 and 5.10. This thesis now discusses the key variables in this study.

1.7.2 Key Study Variables

The key study variables that are used in this study are as follows:

Stage of development. Where a project is in terms of commercial development (early clinical / early development, late clinical / late development, or marketed products).

Average team size. The average number of participants in the project team.

Team duration. How long has the project team been working together on the project.

Physical distance. The distance between team members in kilometres.

Cultural distance. This measure explores the barriers to communicating across cultures, such as the difficulty of 'reading' other team members, communication breakdowns and the challenges of cultural differences. Cultural distance has been quantified by Malik (2013), based on the work of Hofstede (1984).

1.7.3 Research Constructs

The research constructs developed in this study are divided into three categories: impact-mitigating behaviours, management approaches and team performance measures.

Impact-mitigating behaviours

Medical approach. The medical issues that arose for this cohort that were deal with, using medication including melatonin (Sack 2010; Samuels 2012).

Time management. These were strategies such as early arrival (Sack 2010), difficulties in attending morning meetings, and shopping.

Tips & Tricks. These were tips and tricks that survey participants used such as sunlight, diet, exercise, and adequate hydration (Herxheimer & Waterhouse 2003; Sack 2010).

Circadian adjustments. These are simple adjustments to the circadian rhythm that can be made such as adjusting the daily schedule (Cingi, Emre & Muluk 2018), or using light therapy when travelling (Regente *et al.* 2017).

Management approaches

Laissez-faire. The *laissez-faire* management approach is one where senior management has a 'hands off' approach to staff who work in teams (Black & Jamieson 2007; Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007), by asking participants if they were expected to 'push through' fatigue and jet lag, work longer hours when they travel, and fly or have teleconferences outside working hours.

'Concentrate the pain'. The 'concentrate the pain' management approach is where there is a select group of staff who bear the main burden of working across multiple time zones (Welch, Welch & Worm 2007), asking if there were designated business travellers within the team, and if Australians flew more than other members of the team.

'Set the boundaries'. The 'set the boundaries' management approach has organisational-level policies in place to support workers in global teams (Black & Jamieson 2007; Mäkelä &

Kinnunen 2018; Welch, Welch & Worm 2007), with questions about management capping work hours and delegation when a team member travels.

Team performance measures

Financial performance. This is the financial outcomes of the project (Baum, Calabrese & Silverman 2000), examining revenue targets, breaking even, market share and other financial measures.

Technological performance. This is the technological success of the product, measured by functionality, quality, and whether it was rated as successful (Baum, Calabrese & Silverman 2000).

Physical performance. This is the ability to physically perform, and includes issues associated with jet lag such as clarity of thought, memory, concentration, mood, drowsiness and dizziness (Becker, Penzel & Fietze 2015a).

For a detailed description of the variables used and the questions they were derived from, refer to section 5.10. An outline of this document is now presented.

1.8 Outline of the Document

This document is divided into nine chapters, with the chapter structure as outlined below.

Chapter 2 discusses the research context, the Australian biotechnology sector, beginning by defining the term 'biotechnology', then, by analysing the financial aspects of the biotechnology sector, the impact of globalisation in the biotechnology sector and the inevitable consequences of globalisation. It then discusses the emergence of clusters within the biotechnology sector and the identification of several of these clusters, the need for the use of virtual teams in the biotechnology sector, especially in the development of innovative products. The Australian biotechnology sector is then described in detail, including a brief outline of its history and size, and how time zone differences have a powerful impact on operational aspects of the Australian biotechnology sector, thus making it a useful setting for the research question examining time zone differences and performance.

Chapter 3 is the literature review, beginning with innovation management, identifying factors that impede and assist innovation, and specifically innovation in the biotechnology industry. Human chronobiology and the circadian rhythm is addressed, including treatments to ameliorate jet lag that have demonstrated efficacy taken from the scientific literature. Then the composition and nature of globally dispersed teams is discussed, with reference to the concept of virtuality, measures of virtuality, and communication within virtual teams. The impact of organisational psychology and business culture, with particular reference to employees working long hours is then discussed. Finally, definitions and measurements of team performance are examined in the context of globally dispersed teams.

Chapter 4 outlines the conceptual framework of the research, including the four gaps and related measures of distance encountered within dispersed teams (temporal, physical, cultural and language distances) with a particular focus on temporal distance. The mechanisms that are commonly used to mitigate the negative impact of these temporal distances, including managing jet lag as well as communication strategies are outlined. Then the relevant definitions and measurements of team performance and the issues associated with the management of dispersed teams are discussed. Finally, a model is constructed linking these components of physical, temporal, cultural and language distance, team composition, impact-mitigating behaviours and performance.

Chapter 5 describes the research design and procedure. The study uses a mixed methodology, with a qualitative component (a series of interviews) followed by a quantitative component (an online survey). Firstly, the qualitative part of the study is discussed, describing the methodology, sampling techniques, demographic data (gender, subsector, and location) and interview dates, then a description of the data analysis using *NVivo* and the case study methodology as described by Eisenhardt (1989). The procedure for the quantitative component of the research is then outlined, based on relevant questionnaires associated with performance, as well as responses to questions in the quantitative phase of the study. The methodology and data collection are outlined, as well as data analysis using *SPSS*.

Chapter 6 presents findings from the qualitative research (the series of interviews), for further examination and analysis in the quantitative phase of the study), identifying the significant themes that informants have generated through the interviews, commencing with key phrases and moving through the various components of the performance model (physical, temporal, cultural and language distances, team factors, and impact mitigating behaviour), drawing out common experiences or issues that this cohort encounters in working as part of dispersed innovation teams. This is followed by a discussion of the interim findings of this study, describing and exploring these emergent themes related to managing dispersed innovation teams. These themes were incorporated into the online survey created for the quantitative phase of the study.

Chapter 7 presents the results of the quantitative data, the result of 153 surveys taken by workers in the Australian biotech sector who work in globally dispersed in teams across multiple time zones. The data was taken directly from the survey site and analysed using *SPSS* using regressional analysis, extracting key data, and then comparing the data from the survey with data from the relevant literature.

Chapter 8 presents the discussion of the quantitative data, in the light of the theory derived from the relevant literature. This discussion looks at how well workers adjust to working in global teams dispersed across multiple time zones; how current management practice in globally dispersed teams compares with the best practice for these teams, and the potential impact for workers in these globally dispersed teams. From the data some contribution to management theory is postulated, as well as definite, concrete measures that can be taken as a contribution to management practice.

Chapter 9 is the conclusion, bringing together the findings from both the qualitative phase (the series of interviews), and the quantitative phase (the online survey), drawing conclusions from this study.

1.9 Contributions of the Thesis

There are several implications of researching temporal gaps within globally dispersed teams, both theoretical and managerial, which are outlined below.

1.9.2 Theoretical Implications

Having large temporal gaps within teams has a number of theoretical implications: firstly, the impact of working in teams across multiple time zones, or travel across multiple time zones, is not clear in the context of innovation management or an industrial context, although international business travel has been cited as a driver of economic growth (Hovhannisyan & Keller 2010). The impact of time zone differences is well understood (Jehue, Street & Huizenga 1993; Nutting & Price 2017; Reilly *et al.* 2007; Roy & Forest 2017; Waterhouse, Reilly & Edwards 2004; Youngstedt & O'Connor 1999), as is the impact of jet lag (Bonnar *et al.* 2018;

Lee & Galvez 2012; Lemmer *et al.* 2002; Youngstedt & O'Connor 1999) in the context of sport performance, and a large amount of research on the effect of jet lag on humans has been conducted on athletes. However, business travellers, who have different priorities in terms of alleviating jet lag, have not been researched to the same level (refer to Table 1). Secondly, a great deal of the research in jet lag and working odd hours has been examining biomarkers such as melatonin levels (Eastman *et al.* 2005; Lemmer *et al.* 2002; Nickelsen, Lang & Bergau 1991; Paul *et al.* 2009), cortisol levels (Cho *et al.* 2000; Lemmer *et al.* 2002; Nickelsen, Lang & Bergau 1991), body temperature (Arendt *et al.* 1987; Edwards *et al.* 2000; Monk *et al.* 2000; Monk *et al.* 1993), or even a brain scan (Belcaro *et al.* 2008). While these markers may indicate the impact of jet lag on the underlying biology of the test subject, the key issues for business travellers are more likely to be cognitive function and fatigue, and a clear link between these biological markers and executive performance has not been demonstrated in the context of business travel. Thirdly, innovation, whether incremental or disruptive, requires that groups work together in a cooperative process (Cardinal 2001), which is more difficult when a team is geographically and temporally dispersed (Duarte & Snyder 2001, p. 67). And fourthly, organisations can and should develop strategies to maximise productivity and minimise the impact of being part of a team that spans multiple time zones, whether team members travel or not.

Performance indicators are also different for athletes compared with business travellers. For athletes, the performance is mainly physical, and performance is measured with biomarkers such as heart rate and oxygen saturation (Fowler *et al.* 2014), salivary melatonin levels (Paul *et al.* 2009), or physical performance measures such as grip strength (Edwards *et al.* 2000; Paul *et al.* 2009), psychomotor testing (Paul *et al.* 2009) or reaction time and jump height (Fowler *et al.* 2014), which are less relevant to business travellers. Instead, more relevant measures such as cognitive function and wakefulness, both of which are impaired by jet lag (Sack 2010; Waterhouse *et al.* 2007), should be the key measures of performance for members of innovation teams. Vitality has been confused with wakefulness, with business travellers who drive directly after a flight putting themselves and others at risk (Black & Jamieson 2007; Czeisler & Fryer 2006). Most studies researching jet lag use biological markers and physical parameters, and most research is conducted in either healthy volunteers or in athletes, with minimal relevance to the needs and experiences of business travellers.

Having examined the theoretical implications of the contribution of this thesis, the managerial implications of this thesis are now explored.

1.9.3 Managerial Implications

The managerial implications of assessing the impact of temporal dispersion within innovation teams include providing a set of guidelines, practices and policies for managing temporally dispersed teams, and guidelines and policies for the team members who travel internationally and are at risk of experiencing jet lag. Some common behaviours that are used to address jet lag are either poorly supported by evidence, such as exercise (Atkinson *et al.* 2007), or the data is mixed, such as caffeine, where the direction of flight may have an effect (Beaumont *et al.* 2004; Burke *et al.* 2015). Supporting employees who travel internationally across multiple time zones with corporate sleep policies similar to those for smoking or sexual harassment is recommended (Czeisler & Fryer 2006), such as forbidding or preventing staff from taking an overnight flight and then driving to a business meeting, which may improve safety and allow employees to perform at their best. There may also be decisions around who travels within the team, as some potential team members are likely to manage jet lag better than others (Lee & Galvez 2012; Waterhouse *et al.* 2007).

The lack of knowledge on the management of jet lag within the business community is in clear contrast to the sports community, which has published clear and detailed guidelines on the management of jet lag in elite athletes e.g. Samuels (2012).

Finally, a key implication in the Australian context is the nature of overseas partnerships: Australian companies traditionally partner with the United States or Europe (Gilding 2008), which results in a relatively low amount of cultural and language differences (Hofstede 1984), but a high degree of temporal dispersion. Should Australian companies instead partner with nations in the Asia-Pacific region more closely to minimise the temporal distance between team members? In recent years the Australian government prioritised ties with Asia, producing the 'Australia in the Asian Century White Paper', citing the growing economies in the region (Australian Government 2012), although this paper has received criticism for creating unrealistic expectations (Mascitelli & O'Mahony 2014). It can therefore be seen that there are several implications arising from assessing the impact of temporal dispersion within teams.

Having discussed the theoretical and managerial implications of the results of this thesis, the background of this thesis is now summarised.

1.10 Summary

The thesis proposes to address the issue of the impact of time zone differences in global innovation teams, using the Australian biotechnology industry as a case study. As discussed, markets are largely global (Salomo, Keinschmidt & De Brentani 2010), and therefore new innovations are global (Doz, Santos & Williamson 2004), leading to an increase in geographical team dispersion (Gilding 2008). Negative effects may result from geographical dispersion

(Gibson & Gibbs 2006; Lahiri 2010), making globally dispersed innovation teams more challenging to manage (Magni *et al.* 2013).

Time zone differences within these teams can lead to a number of negative impacts on performance, with communication, language, culture and scheduling challenges (Chudoba *et al.* 2005; Ferreira, de Lima & da Costa 2012) adding to the challenge. However, time zone disparity also offers benefits, such as being able to use a 'follow-the-sun' model of workflow (Carmel, Espinosa & Dubinsky 2010). Travel within the teams across multiple time zones can result in jet lag, which can also negatively impact performance (Czeisler & Fryer 2006).

The research question addresses the effect of time zone disparity in the global innovation context, using the Australian biotechnology sector as the setting for the research. The research approach taken is a mixed method approach, with an initial qualitative phase of interviews followed by a quantitative online survey.

Implications of this study have been discussed: firstly, the theoretical implications which includes the impact of working in temporally dispersed globally teams in the context of innovation management; the fact that most research in jet lag has examined biological markers rather than cognitive function and fatigue, both of which are more likely to be of interest to business travellers; the difficulty of groups working together when a team is temporally dispersed (Duarte & Snyder 2001, p. 67); and, strategies that organisations can and should develop to maximise productivity while working across multiple time zones. Managerial implications are also addressed, such as being able to provide a set of guidelines, practices and policies for managing globally dispersed teams, especially members who frequently travel internationally. Staffing decisions are also discussed, with the creation of a managerial class who travels more frequently than their colleagues, as some staff members experience less jet lag (Waterhouse *et al.* 2007). Finally, strategic directions in overseas partnerships are examined: Australian biotechnology companies typically partner with the United States or Europe (Gilding 2008), with a high degree of temporal disparity, Australian companies could instead partner more closely with Asian partners, greatly reducing this temporal distance, but this may increase the cultural distance.

The thesis has been structured to best address the issues raised by the research question, with nine chapters to best incorporate two sets of experimental results due to the use of mixed methodology. The reasons for selecting the Australian biotechnology sector as the context for this research are discussed in detail in chapter 2.

2 Research Context: The Australian Biotechnology Industry

2.1 Introduction

This chapter addresses the context of the research, namely the Australian biotechnology sector. This begins by defining the term ‘biotechnology’, which encompasses a broad variety of disciplines, all having an interface with an aspect of life sciences. It then turns to the scale of the industry globally, with reference to the financial aspects of the biotechnology industry globally, showing how large the industry is and its rapid growth within the last decade. The importance of innovation to this industry is discussed, showing the dependence of the global biotechnology industry on effective innovation management. The impact of globalisation of innovation teams within the biotechnology industry is then explored, with the creation of globally dispersed teams for innovation projects. Virtuality and the concept of virtual teams is then explored, examining the parameters and dynamics of these virtual teams, with reference to innovation management. Within the global biotechnology industry there are hubs or clusters, and the theory and practical aspects of cluster formation in this industry is examined, with reference to Australia (and particularly Melbourne) as a leading hub of biotechnology innovation management. The case of the Australian biotechnology industry and its specific issues is then examined and compared to overseas clusters. Finally, the issue of time zone disparity within the Australian biotechnology industry is discussed, with many members of the Australian biotechnology industry being part of globally dispersed teams; the impact of this on the local industry is then discussed.

2.2 Defining Biotechnology

Biotechnology has a wide range of applications, including developing innovative and life-saving medicines and devices, increasing crop yields and disease-resistant plants for agriculture, food production and waste disposal, and is regarded as a set of technologies profoundly affecting agriculture, food-processing and human health (Gilsing & Nooteboom 2006). Article 2 of the United Nations *Convention on Biological Diversity* defines biotechnology as being 'any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use' (UN Convention on Biological Diversity 1992), and the Organisation for Economic Co-operation and Development (OECD) defines biotechnology as 'the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services' (OECD 2001), and another definition is 'as a means of production, rather than a particular product, involving life sciences' (Hacking 1987, p. 1). Overall, the central idea of biotechnology involves some interaction with life sciences, although the nature of that intersection will vary considerably within the biotechnology sector.

There are a number of streams within biotechnology, including 'red' biotechnology, which is medical and is often a product or vaccine that has been produced using recombinant DNA; 'green' biotechnology, which is agricultural, focusing on plant breeding techniques, including genetically modified plants; and, 'white' biotechnology, which is industrially-focussed and uses enzymes and micro-organisms to make a variety of products, and is a potentially promising approach toward reducing greenhouse gas emissions; as well as 'grey' (environmental), 'blue' (marine and aquatic), 'brown' (desert rehabilitation) and 'gold' (bioinformatics) all considered part of biotechnology (EuropaBio 2013; Kafarski 2012). Because of the large variety of applications within biotechnology, there are a large number of disciplines that come together under the umbrella of biotechnology, including pharmaceuticals, engineering, computer science, and the biotechnology sector is fairly broad and non-homogenous, with these different streams of biotechnology behaving quite differently in terms of funding (Cooke 2004).

Biotechnology has been described as a key player in the world economy, helping drive it (Tylecote 2018). Because of the wide range of applications of biotechnology, including medicine, agriculture, and environmental remediation, the biotechnology sector has a substantial economic impact, which will now be discussed in detail.

2.3 Financial Aspects of the Biotechnology Industry

Globally, biotechnology is a major industry, with revenues approaching US $140 billion annually and a market capitalisation of close to US $1 trillion annually (Ernst & Young 2017, p. 32). The industry is rapidly growing after the global financial crisis of 2008, and revenues and market capitalisation have approximately doubled in the period 2010 to 2016.

Figure 1: Biotechnology Global Revenues

(Ernst & Young 2012, 2013, 2014, 2015, 2016, 2017)

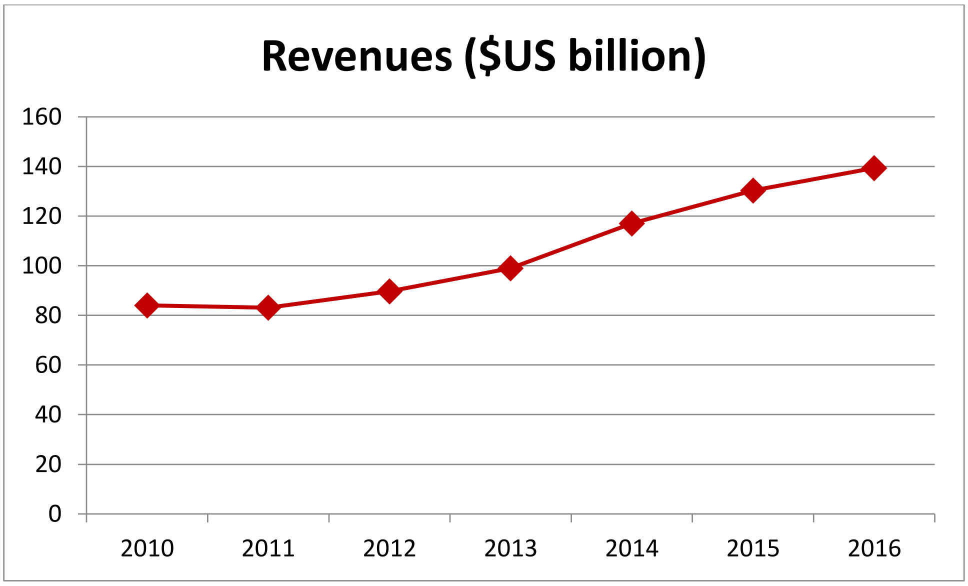
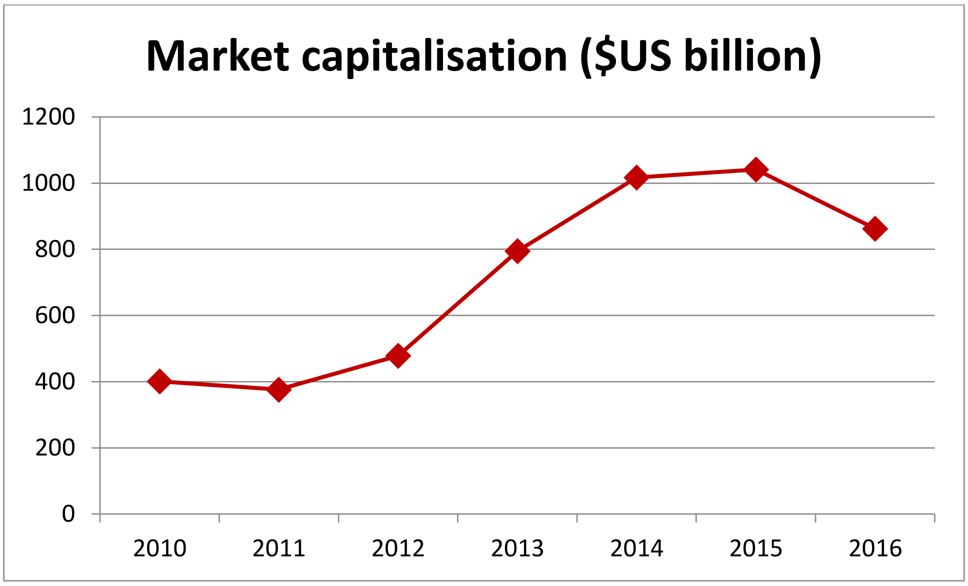


Figure 2: Biotechnology Global Market Capitalisation

(Ernst & Young 2012, 2013, 2014, 2015, 2016, 2017)



The majority of biotechnology is conducted in large hubs, namely the United States, Europe, Australia and Canada (Ernst & Young 2015), with a large amount of Australian biotechnology conducted in Melbourne (Gilding 2008; Summerfield 2017). The importance of these hubs as clusters for biotechnology is discussed further in section 2.5.

Biotechnology encompasses a very broad variety of disciplines, is globally a large sector with approximately $US 1 trillion in revenues, and is rapidly growing, having approximately doubled within the last decade.

2.4 Globalisation in the Biotechnology Industry

Research and Development (R & D) is very much a global activity (Athukorala & Kohpaiboon 2010) with international research collaboration increasing rapidly in recent decades (Chen, Zhang & Fu 2018). The biotechnology sector is heavily globalised, where 'long-distance knowledge transfers are increasingly the norm' (Johnson & Lybecker 2012), and firms offshore to obtain or access niche skills (Thomson 2013). This globalisation of innovation is largely driven by technology (Florida 1997), with locations favoured by such factors as human capital, science and engineering capability, proximity to research hubs and the research capacity of the region, i.e., whether or not it was a research hub (Hegde & Hicks 2008; Siedschlag *et al.* 2013), and has increased at a rapid pace in recent decades (Gerybadze & Reger 1999). The extent of this internationalisation has varied considerably (Laurens *et al.* 2015), and often there is resistance to complete globalisation of R & D, with many companies having a bias in favour of conducting research in the home country (Belderbos, Leten & Suzuki 2013).

Globalisation is a process, with several stages and different modalities. It has been noted that the process of globalisation typically includes a difficult intermediate transition stage as a company moves R & D activities offshore, where 'innovation performance increases in the decentralization stage, decreases in the transition stage, and increases again in the recentralization stage' (Chen, Huang & Lin 2012), and after the initial costs there are benefits to globalising R & D (Hsu, Lien & Chen 2015).

It should also be noted that there are different types of offshoring: captive offshoring (a company's own foreign affiliate) and contract offshoring (external foreign parties); for a small amount of offshoring, contract offshoring has a more positive effect on innovation performance; while for a greater degree of offshoring, captive offshoring has a more positive effect (Steinberg, Procher & Urbig 2017). Globalisation includes several stages including a difficult transition stage, with financial benefits at the end of the globalisation process, and there are different modalities of globalisation that have different impacts depending on the stage of globalisation.

Due to the globalisation of innovation in the biotechnology sector, there has been a rise in the use of virtual teams. Virtual teams are described as having a number of discontinuities within them, including geographical dispersion and time zone disparities (Chudoba *et al.* 2005). Knowledge is virtualised in global team, resulting in connections to global knowledge networks, with a resultant loss of local connectedness (van Geenhuizen & Nijkamp 2012). Virtuality is important in terms of understanding the operation of globalised innovation teams, and this is explored in more detail in section 3.4.

The globalisation of the biotechnology sector has several implications for innovation teams in this sector; there are multiple disciplines that potentially interact in R & D teams; globalisation is a complex process with several stages and different modalities of operation; and because of geographic and time zone dispersion there has been a notable rise of clusters within this sector. The nature and importance of clusters in the biotechnology, with reference to the Australian biotechnology industry, is explored in the following section.

2.5 Clustering in the Biotechnology Industry

Porter (1998) defines clusters as 'geographic concentrations of interconnected companies and institutions in a particular field', affecting competition in three ways: by increasing the productivity of companies based in the area, by driving the direction and pace of innovation, and by stimulating the formation of new businesses which expands and strengthens the cluster itself. Innovative industries typically form clusters, with probably the most famous cluster being Silicon Valley in California for information technology (Engel 2015), with other clusters such as the Italian leather fashion industry (Porter 1998) and the Chilean wine industry (Giuliani 2013), and clusters can be identified using mathematical models (Catini *et al.* 2015). Clusters are therefore readily identifiable geographically concentrated networks of interconnected companies that support each other in a specialised field.

The biotechnology industry has a number of notable clusters, including: in the United States: Boston, San Francisco (Catini *et al.* 2015), San Diego (Casper 2007), Dallas, Research Triangle in North Carolina (Audretsch 2001), and the Capitol District / Maryland (Audretsch 2001; Feldman & Francis 2003); in Europe: Cambridge, Heidelberg, Aarhus, Marseilles, Milano in Europe (Chiaroni & Chiesa 2006) and London (Catini *et al.* 2015); in Asia: Tokyo (Catini *et al.* 2015); and in Australia: Melbourne (Gilding 2008; Summerfield 2017), with new clusters emerging globally (Cooke 2004). The dynamics of the Melbourne biotechnology cluster (and that of the rest of Australia also) is somewhat different to the other clusters listed, due to its isolation, which is discussed in more detail in section 2.6.

In terms of the benefits of clusters in the biotechnology industry, patents developed within clusters will typically have 'a significantly higher impact on subsequent technological developments than patents outside these clusters' (Breitzman & Thomas 2015), and R & D drives innovation (Hall & Bagchi-Sen 2002). To drive innovation, as measured by patent filing, the formation of clusters is extremely beneficial for companies in R & D, including companies in the biotechnology industry.

For biotechnology clusters to be viable, the cluster should include research centres of excellence, a culture of entrepreneurship, and government support and infrastructure (Feldman & Francis 2003), and the creation of clusters is favoured by 'proximity to centres of research excellence and the research and innovation capacity of the region' (Siedschlag *et al.* 2013). For foreign countries looking to set up R & D operations internationally, factors such as the scientific capability and the technological strength of industries are also favoured, thus encouraging the formation and development of clusters (Hegde & Hicks 2008). Scientific talent is a significant factor for a viable cluster, as is the existence of complementary industries to foster networks (Audretsch 2001). In addition, as well as scientific talent and government support, access to capital is crucial, as the biotechnology industry is dependent not only on scientific output, but also on venture financing (Powell *et al.* 2002). Crucial factors for a biotechnology cluster's viability are a pool of scientific talent and expertise to draw upon, an entrepreneurial culture, government support and infrastructure being provided, as well as access to capital, preferably locally.

Another significant factor for the viability of a biotechnology cluster is the formation of networks and knowledge flows. Networking is vital for a firm's survival (Watson 2007), and having strong networks and openness within these networks has a positive effect, not only on the firms, but on the viability of the regional cluster (Eisingerich, Bell & Tracey 2010), and the strength of networks has been shown to predict innovation performance (Wang & Chien 2006). Knowledge flows are vital for a cluster's performance, and 'truly dynamic economic regions are characterized both by dense local social interaction and knowledge circulation', and the geography of knowledge flows map closely with the success of innovation in biotechnology (Gertler & Levitte 2005; Song, Asakawa & Chu 2011). These links within networks include not only direct links, but indirect links also have a beneficial effect on innovation for biotechnology companies within a cluster (Salman & Saives 2005). Links for clusters also need to be global, as fostering a spatial cluster is insufficient in and of itself, but is dependent on global links ('pipelines') that link the cluster with global partners (Bathelt, Malmberg & Maskell 2004).

In summary, biotechnology clusters are geographic concentrations of biotechnology companies in a specific location, and the biotechnology industry is gathered into several large clusters. One of the leading biotechnology clusters in the Asia-Pacific region is Melbourne.

The benefit for a biotechnology company being in a cluster includes a higher-than-average impact of patents, and being part of a biotechnology cluster has a positive impact on R & D. For a biotechnology cluster to be viable, several factors are necessary, including research centres of excellence, an entrepreneurial culture, government support and infrastructure, and access to capital. In addition, biotechnology clusters need substantial networks to support innovation performance, including knowledge flows within the cluster, direct and indirect links, and global connections or 'pipelines' to ensure the viability of the biotechnology cluster. The next section focuses on the biotechnology clusters within Australia.

2.6 The Australian Biotechnology Industry

Australia has a long history of biotechnology research institutions and discoveries in the life sciences (Courtice 1988), in the relative isolation of Australia from the rest of the world is a key factor in this development (Gilding 2008). One of the driving influences in the Australian biotechnology industry was its isolation, as during the First World War medical supplies were not reliable. In 1916 in the height of the war the Commonwealth Serum Laboratories (CSL) was founded, which produced vaccines against cholera and plague, and for Australian troops, typhoid and smallpox (Gidding, Burgess & Kempe 2001). During the influenza pandemic of 1918-1919 CSL produced an influenza vaccine which reduced the death rate from influenza, and in 1939 tetanus toxoid became available which was very successfully used in the Australian armed forces during World War II: among 600,000 troops vaccinated, there was only one case of tetanus (Gidding, Burgess & Kempe 2001). Isolation and neccessity drove innovation in the early development of the Australian biotechnology industry, and isolation is still a strong influence on this industry as it continues to grow today.Australia is one of the four leading hubs of the biotechnology industry worldwide (Ernst & Young 2015, pp. 5, 31), ranked fifth in terms of overall innovation in biotechnology (Scientific American 2018), and is the number one biotechnology location in the Asia-Pacific region, as well as being the premier hub in the Asia-Pacific hub for biotechnology investment (Watkinson 2008). Within Australia, Melbourne is the leading city in terms of biotechnology, and is the leading city for biotechnology in the Asia-Pacific region (Gilding 2008; Summerfield 2017). The Australian biotechnology sector is 'dominated by a relatively small number of firms compared to the US' (Hayward *et al.* 2017), particularly CSL Limited, which accounts for the lion's share of biotechnology market capitalisation in Australia (Australian Government 2015).

Regarding work practices within the Australian biotechnology sector, innovation is typically global (Kafouros *et al.* 2008), with a heavy reliance on partnerships with the United States (Gilding 2008). Team size, particularly in the upper echelons of biotechnology start-ups, is typically small (Jin *et al.* 2016), with diversity among the team positively correlating for success (Bjornali, Knockaert & Erikson 2016), with managers with relevant experience recruited as the start-up company expands (Ener 2017).

The biotechnology industry in Australia enjoys strong support from government at federal, state and local levels. The federal government offers lucrative tax credits for R & D in Australia (Australian Government 2017), although there has been some recent discussion about capping these tax credits, which has raised strong concerns and caused uncertainty in the industry (Mather 2017). At a state level, various Australian states compete with each other to attract investment and the establishment of biotechnology facilities in their state (Norrie 2002), with strong support from the Victorian government (State Government of Victoria 2017) yielding positive results that have exceeded initial expectations (Smith & Pech 2006), and the creation of a biotechnology precinct in the inner Melbourne suburb of Parkville (Melbourne Biomedical Precinct 2017). Similarly, the South Australian government established the TechInSA incubator in the inner Adelaide suburb of Thebarton, which opened in June 2008 and was fully funded by the South Australian Government (TechInSA 2016). The state governments of New South Wales and Queensland have also expressed strong support for the biotechnology industry locating to their state (NSW Government 2014; Queensland Government 2017). At the local level, the City of Melbourne in the state of Victoria, the largest biotechnology hub in the region (Gilding 2008) supported the formation of BioMelbourne, an industry-led membership association for local biotechnology companies and organisations to foster collaboration (BioMelbourne Network 2018), and the creation of a centralised database of biotechnology organisations in the state of Victoria, the Victoria BioPortal (City of Melbourne 2017). To sum up, the Australian biotechnology industry was founded due to isolation, which has proven to be a challenge for the industry, is dominated by a small number of companies, and generally enjoys strong support from government at the federal, state and local levels. The consequences of the isolation are now explored in more depth.

The biotechnology industry globally is reliant on networks (Gilding 2008; Powell 1996; Powell, Koput & Smith-Doerr 1996), and a large 'global footprint' is beneficial in managing new product development (Dubiel, Durmusoglu & Gloeckner 2016; Sivakumar *et al.* 2011); the Australian biotechnology industry is no exception. There are strong global networks and alliances in the Australian biotechnology industry (Pitt *et al.* 2006), and it is highly networked (Mohannak 2007), with particularly strong links to the United States (Gilding 2008). However, in a series of 18 interviews of key stakeholders in an Australian consortium, these networks were stated to be deficient, and interview subjects stated that the life sciences subsector with the Australian biotechnology industry was 'too fragmented and uncoordinated', and that the network was insufficiently robust (Marot *et al.* 2005), lacking cohesion and infrastructure to support future growth (Terziovski & Morgan 2006).

One of the key distinguishing features of the Australian biotechnology industry is its distance and isolation from the other major biotechnology hubs, particularly the United States and Europe, and a large number of geographically dispersed teams (Gilding 2008; Gittelman 2007). Many workers in this sector frequently travel long distances, experiencing ‘constant travel and periodic displacements’, resulting in high financial and personal cost (Fontes 2005), and strategies to deal with this isolation include ‘gruelling travel schedules, overseas consultants and branch offices’ (Gilding 2008). There is downward pressure on travel costs and the development of travel polices within companies in the face of increasing company travel (Gustafson 2012a) in the context of the amount of business travel increasing (Statista 2018; Tarrant 2017), particularly within the Australian biotechnology industry.

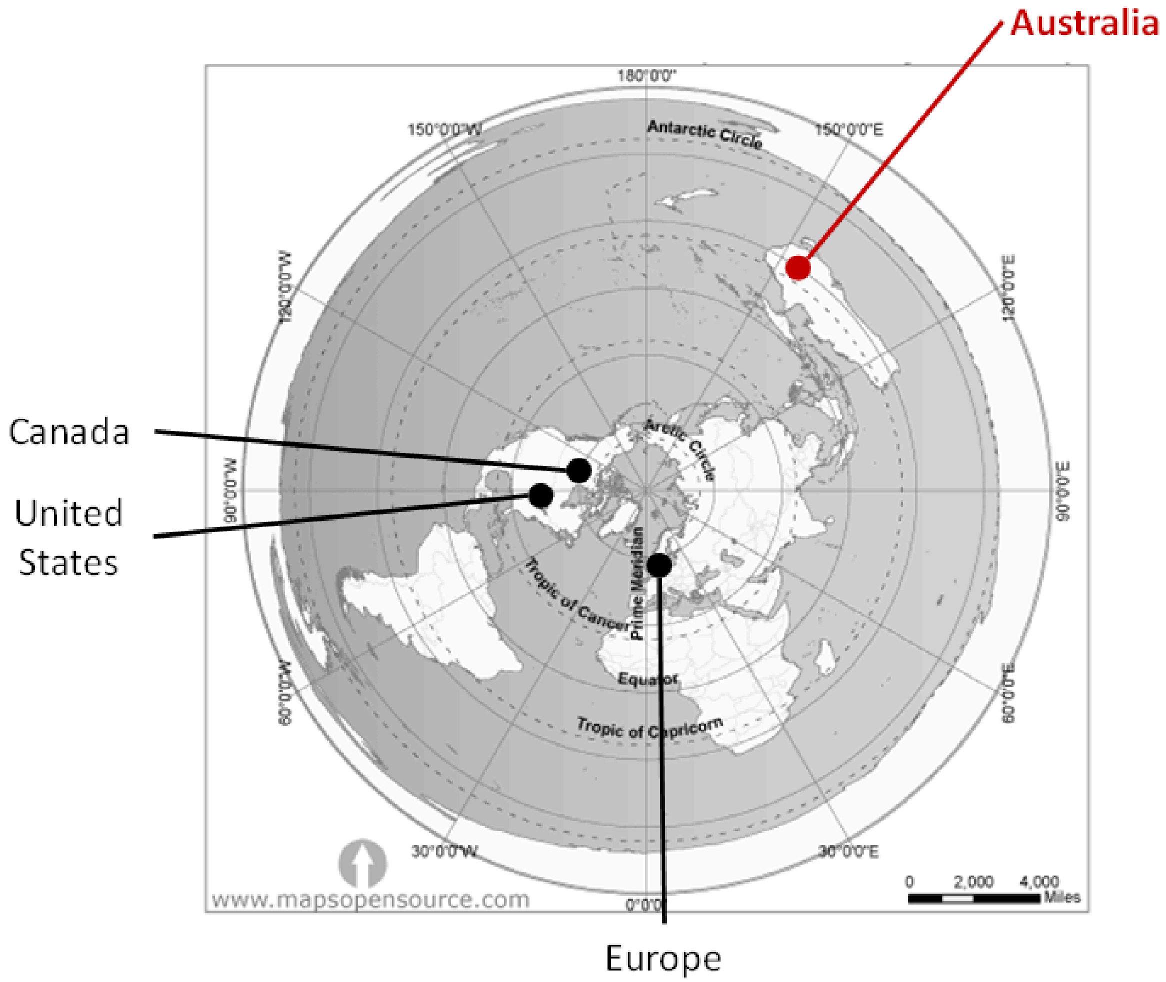
Apart from the physical isolation of the Australian biotechnology sector, there are other challenges facing this sector. These include navigating a complex intellectual property landscape regarding patents and difficulties in negotiation with downstream partners (Nicol & Nielsen 2005), and challenges in effective knowledge management globally for small Australian biotechnology companies (Clarke & Turner 2004). Funding is also a challenge for this sector, requiring companies to ‘build a bridge to the US... find a way to tap into that market, and find a way to become part of that network so that you can get access to some types of funding and you can get access to the deal making’ (Gilding 2008). Thus, there is a need at a very early stage for Australian biotechnology companies, even small ones, to go global in their strategy. Funding for R & D in biotechnology has several challenges, including the long duration of programs (when investors are typically looking for returns in shorter time periods), the lack of firm timelines in building R & D capability, the high levels of uncertainty in terms of execution, and upfront costs that cannot be recouped (Standing, Standing & Lin 2008). As a direct result of the challenge with obtaining adequate funding, many Australian biotechnology companies list their Initial Public Offering at a discounted rate and at a relatively early stage when the companies are still relatively small (Collignon 2017; Herpin, Karuso & Foley 2005; Vitale & Sparling 2004), putting them at a disadvantage.

It can be seen that while the Australian biotechnology sector has strong support at all three levels of government, it also faces some unique challenges, mainly in the area of isolation and distance, many workers in this industry experiencing the 'tyranny of distance' and resulting in 'gruelling travel schedules' (Gilding 2008). Other challenges include navigating a complex patent landscape (Nicol & Nielsen 2005) and attracting adequate funding (Vitale & Sparling 2004) requiring strong overseas networks (Gilding 2008; Mohannak 2007). The isolation of the Australian biotechnology industry, not only physically but temporally (i.e. in terms of time zone differences) make it a good setting to examine the effect of time zone disparity on the performance of dispersed teams in a global innovation context, specifically the effect of time zone differences on the performance of global innovation teams.

2.7 The Issue of Time Zone Disparity and the Australian Biotechnology Industry

The isolation that the Australian biotechnology industry is subject to is not just physical, i.e. in terms of distance as measured in kilometres, but also temporal, i.e. in terms of time zones as measured by hours. Australia is one of the four key hubs of the biotechnology industry worldwide, along with the United States, Europe and Canada (Ernst & Young 2015, pp. 5, 31), and Australia is isolated from these key hubs by both distance and time zone disparity. The azimuthal projection of the world (Figure 3) displays relative isolation of the Australian biotechnology industry temporally compared with other biotechnology hubs temporally.

Figure 3: Azimuthal projection showing major biotechnology hubs



As discussed, the biotechnology industry globally is highly networked (Powell 1996; Powell, Koput & Smith-Doerr 1996), and the Australian biotechnology industry is no exception (Gilding 2008; Mohannak 2007; Pitt *et al.* 2006), although these networks are sometimes insufficiently robust (Marot *et al.* 2005). The time zone disparity between Australian and overseas partners contributes to this, which is now addressed.

Time zone disparity within teams can have a significant negative effect on communication due to the asynchronicity between colleagues (Yu, Guan & Ramaswamy 2016), although this can be offset by a potential benefit of this time zone disparity experienced by Australian biotechnology workers with their overseas counterparts is to be able to exploit a 'follow the sun' model of workflows (Carmel, Espinosa & Dubinsky 2010). The issue of the effect of time zone disparity on productivity is addressed in more detail in chapter 3, but it appears to be potentially a significant issue for the Australian biotechnology industry.

2.8 Summary

In summary, Australia is a significant biotechnology hub in the Asia-Pacific region, and is heavily networked to many overseas hubs, particularly the United States (Gilding 2008), collaborating internationally and forming dispersed teams across multiple time zones (Mohannak 2007; Powell, Koput & Smith-Doerr 1996). Australia also has a high degree of time zone disparity with the other major biotech hubs (North America and Europe), leading to challenges in terms of working with globally dispersed teams in North America and Europe.

Many industries driven by innovation (such as information technology and biotechnology) rely on geographically dispersed teams, and the data from this study may reveal ways to ameliorate the adverse effects of temporal dispersion, while being able to take advantage of the benefits of 'following the sun' in terms of workflows (Carmel, Espinosa & Dubinsky 2010).

The Australian biotechnology industry is a good setting for this study because firstly, Australian biotechnology companies typically form dispersed innovation teams, rather than restricting their teams to a collocated centre (Gilding 2008), and secondly, biotechnology is driven by R & D, so the teams are typically innovative (Bernstein & Singh 2006). Therefore, investigating this effect in the Australian biotechnology industry will contribute to theory on the effect of time zone disparity globally. This allows the possibility of constructing a model that examines the effects of temporal distance while accounting for other effects from physical distance, cultural differences and language issues, which are expected to contribute to an understanding of the dynamics of geographically dispersed teams. Because there is a high degree of both innovation and temporal dispersion in project teams, the Australian biotechnology industry makes an excellent setting for studying the effects of temporal distance on the performance of global innovation teams.

3 Literature Review

3.1 Introduction

This chapter brings several research areas together: innovation management, virtual teams, chronobiology, organisational psychology, and measures of team performance are discussed. These disparate fields of study are examined separately and then brought together to provide the background for the research question. Innovation management is outlined, examining the drivers and dynamics of innovation and how innovation is measured, including disruptive innovation. The globalisation of innovation and national innovation systems are discussed. Virtual teams are then examined by first defining a virtual team and measures of virtuality, and the challenges of working in and managing a virtual team are discussed. Issues such as communication and trust are addressed, as well as the significance of temporal disparity and how it contributes to virtuality. Organisational psychology is discussed, outlining organisational culture and values. The negative effects of working long hours and frequent international business travel across multiple time zones are addressed to provide context for this study. The field of chronobiology, the area of biology examining the circadian rhythm, is examined with a focus on jet lag and the therapies used to alleviate the potentially negative effects of jet lag on performance. Finally, performance and its measures are examined at the individual, team and firm levels, with emphasis on the effects of temporal disparity within teams, and the effect of temporal distance on team members, especially business travellers who travel frequently.

These fields of study are then drawn together and summarised, about the research question '*What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?*' to provide a suitable background for reviewing the literature relating to this research question.

3.2 Innovation Management

3.2.1 Introduction to Innovation Management

Innovation management is now discussed with reference to biotechnology and virtual teams. Innovation is defined by Fetterhoff and Voelkel (2006) as 'the commercialization of a novel technology that provides the customer with new capability', with three key components: enabling technology, customer utility and commercialisation. Innovation has several drivers, can be supported by national or regional systems of innovation, is global in scope, and is dependent on knowledge creation.

In the biotechnology sector, innovation is complex with both incremental and disruptive innovations (Niosi & McKelvey 2018), and biotechnology is dependent on and driven by that innovation (Fetterhoff & Voelkel 2006; Gilsing & Nooteboom 2006; Rothaermel & Hess 2007; Wu 2013). Innovation management is discussed in the context of the global biotechnology industry, with reference to the Australian biotechnology industry.

3.2.2 Drivers of Innovation

A number of drivers of innovation have been identified (Niosi & McKelvey 2018; Taalbi 2017), as well as a variety of frameworks for innovation (Anderson, Potočnik & Zhou 2014; Etzkowitz & Leydesdorff 2000; Leydesdorff 2000). Drivers of innovation include infrastructure such as technological sophistication, a pool of qualified talent, financial resources, investment in education and training, openness to international trade, favourable R & D tax policies (Furman, Porter & Stern 2002), adequate patent protection (Furman, Porter & Stern 2002; Moser 2013), new technological opportunities (Taalbi 2017), technology transfer partners (Markman *et al.* 2005), an innovation culture (Hurley & Hult 1998), and risk-taking behaviour (Leenders & Voermans 2007).

Market orientation, defined as the three components of customer orientation, competitor orientation and interfunctional coordination (Narver & Slater 1990), has been shown to have a positive impact on innovation success (Atuahene-Gima 1996; Dibrell, Craig & Hansen 2011), particularly in highly competitive environments (Grinstein 2008) and for new products (Kirca, Jayachandran & Bearden 2005). Innovation also affects market orientation and performance (Han, Kim & Srivastava 1998). However, an imbalance of the three components of market orientation can lead to failure (Jasper, Leenders & O'Shannassy 2019).

There is some, but not complete, consensus as to the social and economic factors that drive innovation (Taalbi 2017). Factors that hamper innovation include cost barriers, knowledge barriers, market barriers, regulation barriers (D'Este *et al.* 2012), financial constraints, market structure and lack of demand (Pellegrino & Savona 2017).

Having discussed factors that drive and hamper innovation, this review now turns to the dynamics of innovation.

3.2.3 Dynamics of Innovation

There are two competing views of innovation, a Schumpeterian one and a Penrosian one (Cooke 2003). Schumpeter's view was that innovation is cyclical; as new technologies make other technologies obsolete, this results in 'creative destruction' (Schumpeter 1947). Penrose's view centred on strategic resources that are rare, difficult to duplicate, and valuable, over which a firm has control (Penrose 1995).

An example of Schumpeter's 'creative destruction' is cited by Tushman and O'Reilly (1996), where companies that used vacuum tube technology were swept away by new technology innovations. The Schumpeterian perspective has been used to explain the economic crisis of 2008 (Archibugi 2017) as an inability to innovate. By way of contrast, the Penrosian perspective has been applied to the study of project-based, service-enhanced firms such as biotechnology (Gann & Salter 2000), taking a resource-based view. For biotechnology companies, both views of innovation have points of merit: from the Schumpeterian perspective, the biotechnology industry is in and of itself providing the disruptions resulting in 'creative destruction' (Madhok & Osegowitsch 2000), while applying the Penrosian perspective, patent laws supply a company a monopoly on a new product for several years, such as the blockbuster drug sildenafil (Viagra) for erectile dysfunction (Pike 2001, p. 8).

In addition to the contrasting Schumpeterian and Penrosian perspectives for innovation, there are also multiple levels of innovation within the biotechnology industry: the individual, firm, and network levels (Rothaermel & Hess 2007). Having examined the dynamics of innovation, this review now reviews disruptive innovation.

3.2.4 Disruptive Innovation

There are also two main types of innovation defined in the literature, sustaining versus disruptive. The term 'disruptive innovation' was coined by Christensen (1997), and is defined as an innovation dramatically disrupts the market, or 'an innovation with radical functionality, discontinuous technical standards, and/or new forms of ownership that redefine marketplace expectations' (Nagy, Schuessler & Dubinsky 2016), although there is some debate around the definition of a disruptive innovation (Christensen, Raynor & McDonald 2015) and claims that the term has been overused (Christensen *et al.* 2018). This contrasts with sustaining innovations such as a new model of a microprocessor, which is a minor upgrade of an existing product (Schmidt & Druehl 2008). Disruptive innovations can be divided into first order changes, which are restricted to a certain market or industry, and second order changes, which have an impact across society (Schuelke-Leech 2018). Disruptive innovations are also distinct from disruptive technologies, which have ‘the potential to create disruptive innovation’ such as electric cars (Li, Porter & Suominen 2018; Millar, Lockett & Ladd 2018). Frameworks for disruption have been proposed, focusing on the level of disruption (firm or industry) (Kilkki *et al.* 2018) or the diffusion pattern (high-end, low-end, new market) of the disruption (Schmidt & Druehl 2008).

Markets with higher entry barriers are more susceptible to disruption (Klenner, Hüsig & Dowling 2013), and this disruptive innovation can be cultivated by entrepreneurs to create market opportunities (Hang, Garnsey & Ruan 2015). However, disruptive innovation can result in established firms being displaced by new ones as a result of the innovation (Feder 2018), as firms fail to identify the new market due to the disruptive innovation or technology (Vecchiato 2017). Because of this, technology planning, specifically, having a strategy to manage the development of technology, is vital to ensure a company stays competitive (Bloem da Silveira Junior *et al.* 2018).

In summary, there are two main types of innovation, sustaining and disruptive. Sustaining innovation is a relatively minor change, whereas disruptive innovation is a more radical change. While there is some disagreement around the definition of a disruptive innovation, it is generally described as a change that alters the market. Due to disruptive innovation, new opportunities can be created, and established firms can be displaced, which makes technology planning important. This is particularly relevant to the biotechnology sector, which is frequently disrupted by innovative technology (Birkinshaw, Visnjic & Best 2018; Munos & Orloff 2016).

Having examined disruptive innovation, this review now turns to the measurement of innovation.

3.2.5 Measuring Innovation

A company's innovation effectiveness, measured in terms of new product introduction, is associated with a positive effect on business performance (Hall & Bagchi-Sen 2002). It is vital to be able to measure this innovation using metrics such as ideas funded, return on investment, CEO commitment, and long-term customer adoption (Mankin 2007). The efficiency with which new technological innovations are developed is an important measure of innovation success (Cruz-Cázares, Bayona-Sáez & García-Marco 2013), although incremental innovation is quite different from radical innovation in its nature (Nagy, Schuessler & Dubinsky 2016; Popadiuk & Choo 2006).

Measuring innovation can use a quantitative approach, such as the number of patents (Hagedoorn, Lokshin & Malo 2018; Niosi & McKelvey 2018), patents *per capita per annum* (Furman, Porter & Stern 2002), return on investment (Mankin 2007; Richard *et al.* 2009), the amount of venture capital investment and revenues (Gittelman 2006), number of users (Muller & Peres 2017), market penetration (Muller & Peres 2017), adoption rate (Muller & Peres 2017; Rand & Rust 2011; van Eck, Jager & Leeflang 2011), time to takeoff (Mukherjee 2014; Muller & Peres 2017), market share (Muller & Peres 2017; Uchida & Shirayama 2008), or profit (Muller & Peres 2017; Richard *et al.* 2009).

An approach that is intermediate between qualitative and quantitative is the balanced scorecard approach, which has components such as translating a vision and communication rather than short term sales targets (Kaplan & Norton 1996; Perkins, Remmers & Grey 2014), although the use of the balanced scorecard is often only of marginal benefit (Wiraeus & Creelman 2019).

Richard *et al.* (2009) performed a comprehensive review of performance management and found that almost a quarter of peer-reviewed management journal articles that measured firm performance used surveys alone to assess performance. In the biotechnology sector in Canada, a survey methodology was used to assess firm performance (Hall & Bagchi-Sen 2002), and because of the challenges of assessment and the frequent use of surveys to measure firm performance, surveys are used to assess firm performance for this study.

The measurement of innovation is vital, and innovation is a global process. This globalisation of innovation is now discussed.

3.2.6 The Globalisation of Innovation

Firms tend to have a degree of internationalisation to be innovative (Cano-Kollmann, Hannigan & Mudambi 2018; Kafouros *et al.* 2008); therefore, innovation is typically global. This globalisation of innovation results in increased competition internationally and greater collaboration with overseas partners (Archibugi & Iammarino 1999). A conceptual framework for global innovation has been proposed by Binz and Truffer (2017), which includes generation of resources in global subsystems and establishing structural couplings. In the biotechnology industry, there are typically a significant number of alliances forming vital global channels of communication (Bathelt, Malmberg & Maskell 2004; Madhok & Osegowitsch 2000). In the local context, Australian biotechnology companies typically partner overseas, especially with partners based in the United States (Gilding 2008; Guan, J & Chen, Z 2012).

While innovation is globalised, systems to support and enhance innovation can be applied at national, regional, sectoral, or technological levels (Carlsson *et al.* 2002), and include a series of extremely complex interactions at these various levels (Bartholomew 1997), which are now discussed.

3.2.7 National and Regional Systems of Innovation

National innovation systems (Sharif 2006), measured by the OECD, are defined as a 'set of institutions that (jointly and individually) contribute to the development and diffusion of new technologies. These institutions provide the framework within which governments form and implement policies to influence the innovation process' (Metcalfe 1995). These national innovation systems are dependent on the 'development of the "innovation system", the quality of "governance", the character of the "political system" and the degree of "openness"' (Fagerberg & Srholec 2008), and the national innovative capacity of a nation is measured in patents *per capita per annum* (Furman, Porter & Stern 2002). Government policy can have an impact on innovation performance (Samara, Georgiadis & Bakouros 2012), as can industry associations (Watkins *et al.* 2015), and absorptive capacity (Castellacci & Natera 2013). National innovation systems are crucial to fostering innovation, and the differing strengths of national innovation systems between different nations explains the great variation in innovative capacity.

The efficacy of national innovation systems can be modelled (Guan, J & Chen, K 2012), for example, East Asia (Dodgson *et al.* 2008; Hu & Mathews 2005), China (Hu & Mathews 2008), and Denmark (Lundvall *et al.* 2002). Lessons from the modelling in Denmark provided a number of key findings, including 'most of its [Denmark's] innovations are incremental and experience-based rather than radical and science-based' (Lundvall *et al.* 2002). In terms of innovation productivity in healthcare, Scandinavia and Switzerland have been shown to be the most productive (Proksch *et al.* 2018), and Sweden's national innovation policy has been held up as a model for other nations (Edquist 2018).

Apart from national innovation systems, there can also be regional innovation systems. These regions can encompass several nations, such as the Biovalley cluster covering Switzerland, France and Germany (Chiaroni & Chiesa 2006), as well as within a nation, such as the state of Victoria within Australia (Gilding 2008), and these regional innovation systems can interact with national innovation systems (Chung 2002) and can be measured (Hauser *et al.* 2018). Investment is tied to these regional innovation systems, with R & D investment from universities and research institutions, and investment firms (Jiao *et al.* 2016), and supported by social capital with networks among professionals (Laursen, Masciarelli & Prencipe 2012). Absorptive capacity, defined as a company's ability to access external knowledge, also has a positive effect on regional innovation systems (Lau & Lo 2015). However, if a region has a strong knowledge base and broad specialisation, the resulting network structures can be rather fragmented (Cantner, Meder & Ter Wal 2010).

'The exchange of information is the lifeblood of product development' (Eppinger 2001), and knowledge creation and management is crucial in innovation, and information networks are vital (Rothschild & Darr 2005). Internal communication is important for the management of innovation (Eppinger 2001), and time zone differences make this communication more difficult (Daim *et al.* 2012). While knowledge is developed at an individual level, this is in turn articulated and amplified by an organisation (Nonaka 2000), and this process is made more difficult by time zone dispersion. Innovation and knowledge creation are distinct but closely related concepts (Popadiuk & Choo 2006). The concept of '*ba*', a Japanese word meaning 'place', has been used to describe a platform for knowledge: a shared space that can be physical, virtual, mental, or any combination of these three elements (Ikujiro & Noboru 1998). Cultural differences can also have a substantial effect on knowledge networks (Ibert & Müller 2015). Knowledge management is complex, essential to innovation, and is made more difficult in teams that are dispersed across multiple time zones.

Related to knowledge management is the concept of open innovation, defined as the 'purposive use of inflows and outflows of knowledge to, respectively, accelerate internal innovation, and expand the markets for external use of innovation' (Chesbrough 2006). Open innovation practices affect national systems of innovation, by reinforcing the importance of the national innovation system, improving its effectiveness, and diversifying its networks (Wang, Vanhaverbeke & Roijakkers 2012). This can also be seen in regional innovation systems, such as the example of the Italian region of Emilia-Romagna (Belussi, Sammarra & Sedita 2010). Open innovation is typically implemented in stages (Chiaroni, Chiesa & Frattini 2011), and is used in the biotechnology sector (Bianchi *et al.* 2011; Fetterhoff & Voelkel 2006; Pullen *et al.* 2012).

Two modes of innovation have also been described: a 'Science, Technology and Innovation' mode, which is based on intellectual property, and a 'Doing, Using and Interacting' mode, which is more informal, and experiential (Jensen *et al.* 2007). The 'Doing, Using and Interacting' mode of innovation led to reduced knowledge barriers in a study in Germany (Thomä 2017), and combining these two modes is likely to have the best outcome for companies (Jensen *et al.* 2007).

In the biotechnology sector knowledge flow has distinct spatial patterns (Coenen, Moodysson & Asheim 2004), and knowledge management has been used successfully in the biotechnology sector (Canongia, Antunes & Freitas Pereira 2004). The nature of these knowledge flows has implications for the Australian biotechnology sector: while Australia is relatively isolated from other biotechnology hubs (see Figure 3), there are strong links between Australian biotechnology companies and their overseas partners (Gilding 2008). Although ‘projects involving local ties are more likely to be patented by a firm than are projects involving distant contacts, both because proximity is conducive to innovation’ (Gittelman 2007), the Australian biotechnology sector’s physical isolation puts it at a significant disadvantage relative to its overseas counterparts.

Political factors play a significant role in innovation (Courvisanos 2009; Niosi & McKelvey 2018); for example, use of genetically modified organisms is well-supported in pharmaceuticals but not in agriculture (Herring & Paarlberg 2016), and stem cell research remains controversial in many countries (Jain & George 2007; Robertson 2010). According to Cardwell’s Law ‘no nation has been very creative for more than a historically short period’ (Taylor 2016), highlighting the importance of politics in innovation.

National and regional innovation systems support innovation, including biotechnology. For innovation knowledge creation is vital, being distinct but related to innovation. Open innovation has become prominent in the biotechnology sector, with differing approaches to innovation. Australian biotechnology companies are at a disadvantage due to a lack of local knowledge flows, and political factors are significant. Having discussed the importance of national and regional innovation systems in relation to the biotechnology sector, this literature review now turns to the innovation process in biotechnology.

3.2.8 Innovation in Biotechnology

As already discussed, the biotechnology industry is dependent on innovation: ‘innovation is critical for firm sustainability in the biotechnology industry’ (Hall & Bagchi-Sen 2002), with intellectual property at the core of biotechnology innovation (Marot *et al.* 2005), which is thoroughly globalised (Cooke 2005; Madhok & Osegowitsch 2000). There are multiple levels of innovation within the biotechnology industry: individual, firm, and network (Rothaermel & Hess 2007), and given the diverse areas that biotechnology includes (Canongia, Antunes & Freitas Pereira 2004), innovation within this sector is also diverse (Bernstein & Singh 2006) and complex (Niosi & McKelvey 2018).

For the pharmaceutical subsector of the biotechnology industry future performance is linked to R & D innovation (Wu 2013); 'big pharma cannot afford to rest on its laurels' (Ernst & Young 2001). The discovery process in this subsector is cyclical (Gilsing & Nooteboom 2006), and smaller companies may be nimbler (Langowitz & Graves 1992; Malerba & Orsenigo 2002). Similarly, for medical devices, another subsector of the biotechnology industry, performance is reliant on innovation (Chatterji 2009; Pullen *et al.* 2012), as is the agricultural subsector (Possas, Salles-Filho & da Silveira 1996; Vanclay, Russell & Kimber 2013).

Innovation in the biotechnology sector has several challenges, including access to funding, the high level of regulation, and a high degree of fragmentation (Herzlinger 2006). Not only is a strong R & D sector necessary, but an entrepreneurial culture within academia is also needed (Todt *et al.* 2007).

Having outlined the importance of innovation in the biotechnology sector, this review now turns to the Australian context.

3.2.9 Innovation in Biotechnology in Australia

As previously discussed, Australia is a hub for the biotechnology industry (Gilding 2008) which is dependent on innovation (Hall & Bagchi-Sen 2002) and linked globally (Gilding 2008; Rogers

2004). Despite significant global alliances, Australian biotechnology companies tend to remain fairly small due to lack of funding (Standing, Standing & Lin 2008).

The biotechnology sector in Australia enjoys a high level of government support (discussed in section 2.6) at all levels of government. Melbourne is the hub of the biotechnology industry in the Asia-Pacific region (Gilding 2008) due to the city 'articulating a scientific vision and strategy; having skilled and reputable staff; securing an intellectual property web; accessing first-class facilities and equipment; possessing a range of business expertise; minimising cycle time; locating manufacturing expertise; obtaining seamless funding; establishing collaborative partnerships; proactively addressing ethical issues; and expertly managing regulatory requirements' (Terziovski & Morgan 2006), and the state of Victoria has been used as a case study for the development of biotechnology (Smith & Pech 2006). As a result of this government support innovation in biotechnology in Australia is cost effective (Lichtenberg 2017).

Knowledge networks with strong links to overseas partners (particularly the United States) are prominent in the Australian biotechnology industry (Gilding 2008; Rogers 2004), although it is physically isolated from other major biotechnology hubs (Gilding 2008). This isolation is not only in terms of physical distance, but also temporal distance, as Australian time zones are greatly disparate to those in North America and Europe.

3.2.10 Summary of Innovation

The biotechnology industry is dependent on innovation (Hall & Bagchi-Sen 2002), and several components have been identified as supporting innovation, including an available pool of talent for R & D, financial resources, favourable R & D tax policies (Furman, Porter & Stern 2002) and finding suitable business partners (Markman *et al.* 2005). While Australia scores strongly in most of these parameters, its relative isolation from other major biotechnology and investment hubs makes finding business partners more challenging. Despite this, Australia rates highly in terms of biotechnology innovation (Gilding 2008). Because of its physical isolation and close links with overseas hubs, the Australian biotechnology sector is an excellent setting for researching the effect of time zone disparity within globally dispersed teams. These globally dispersed teams are typically virtual or have most of the components of a virtual team, and the nature of virtuality within teams is now discussed in the next section.

3.3 Virtual Team Management

3.3.1 Introduction to Virtual Team Management

This section of the literature review examines teams, defining virtual teams and measures of virtuality, then turns to the challenges faced by virtual teams, their effective management, trust within these teams, and virtual teams and innovation with reference to biotechnology, and challenges in communication, particularly teams that work across multiple time zones.

3.3.2 Definition of Virtual Teams

Teams have been defined as 'collectives who exist to perform organizationally relevant tasks, share one or more common goals, interact socially, exhibit task interdependencies, maintain and manage boundaries, and are embedded in an organizational context that sets boundaries, constrains the team, and influences exchanges with other units in the broader entity' (Kozlowski & Bell 2003, p. 334), with the leading characteristic of a team is having one or more common goals. A virtual team has been defined as a team that has discontinuities, in terms of geography (i.e., not collocated), having time zone disparity, cultural diversity, differing work practices, organisation, and technologies, dependence on electronic communication, and working with people who have never met face-to-face (Chudoba *et al.* 2005; Foster *et al.* 2015, pp. 7-13; Gibson & Gibbs 2006). Virtual teams offer a number of advantages such as access to leading global talent (Hertel & Orlikowski 2015), building teams with optimum membership and remaining relatively lean (Townsend, DeMarie & Hendrickson 1998), and are likely to remain prominent (Bell & Kozlowski 2002) with the use of virtual teams increasing (Gilson *et al.* 2015).

For innovation teams, the size, nature, function and distribution of these teams can affect their performance, particularly for collocated teams. Large team size has led to social loafing in collocated teams (Alnuaimi, Robert & Maruping 2010; Chidambaram & Tung 2005), but not in virtual teams (Gibson & Gibbs 2006). However, managing virtual teams poses significant challenges, which are now discussed.

3.3.3 Challenges of Virtual Teams

Team size, cultural and language mix, and dispersion pattern of the team both physically and temporally, all has impact on performance. Virtual teams are typically more task-oriented than socially-oriented (Standing, Standing & Lin 2008) and more culturally diverse, leading to challenges (Muethel & Hoegl 2010). Cultural differences within teams can lead to less work satisfaction and greater conflict (Staples & Zhao 2006), and it can be difficult to distinguish cultural effects from virtual effects (geographic dispersion, reliance on electronic communication, time zone disparity) on performance (Gibson *et al.* 2014). In virtual teams, diversity, creativity and geographical configuration are important for performance (O'Leary & Mortensen 2010; Polzer *et al.* 2006; Somech & Drach-Zahavy 2013). Virtual team participation can hamper creativity (Martins & Shalley 2011), which is problematic for innovation.

There are substantial challenges with virtual teams, and the effective management of these teams is now discussed.

3.3.4 Management of Virtual Teams

There is a wealth of literature on the effective management of dispersed teams. Open, effective communication and trust among members have been cited as important factors in enhancing dispersed team performance (Hacker *et al.* 2019; Jarvenpaa & Leidner 1999; Smith & Blanck 2002) and managing a geographically dispersed team increases the need for effective teamwork and communication (Hoegl, Ernst & Proserpio 2007). It has been suggested that key components of virtuality, such as geographic dispersion and dependence on technology, creates 'paradoxical tensions', which offer both opportunities and challenges for managing virtual teams (Purvanova & Kenda 2018).

Managing virtual teams is completely different to that of collocated teams, requiring inspirational leadership and trust (Joshi, Lazarova & Liao 2009; Liao 2017; Zigurs 2003), especially for virtual innovation teams (DeCusatis 2008), and cultural diversity is also a challenge (Joshi & Lazarova 2005). Best practices for managing virtual teams include team-based reward systems, selective hiring, understanding diversity and establishing and maintaining trust (Lurey & Raisinghani 2001; Malhotra, Majchrzak & Rosen 2007).

Trust within virtual teams is more important for a virtual team's success than for a collocated team (Cascio & Shurygailo 2003; Muethel, Siebdrat & Hoegl 2012). Trust typically develops rapidly (Jarvenpaa, Knoll & Leidner 1998), but is fragile (Crisp & Jarvenpaa 2013; Jarvenpaa & Leidner 1999) and has a positive impact on team performance (Alsharo, Gregg & Ramirez 2017; Politis 2003). Team configuration has an impact on the trust, as subgroups of collocated members have a negative impact on trust (Polzer *et al.* 2006). This trust becomes particularly important with asynchronous communication due to time zone differences (Kanthak & Hertel 2016), such that time zone differences add an extra level of difficulty.

Another factor described in the effective management of dispersed teams is ‘inspirational leadership’, which is defined as communicating a compelling vision, having confidence and energising the team (Joshi, Lazarova & Liao 2009). Dispersed teams also appear to be less hierarchical in nature, with shared leadership behaviours (Hoch & Kozlowski 2014), modified by cultural and societal factors (Muethel & Hoegl 2010). Cultural awareness is also a critical success factor in leading dispersed teams, as they are usually multicultural (Zander, Mockaitis & Butler 2012), although the authors state that cultural diversity in dispersed teams can be leveraged to advantage. To sum up, effective strategies in the management of dispersed teams include open and effective communication, building trust among the team rapidly, inspirational leadership, fostering shared leadership, and cultural sensitivity. However, how temporal distance affects the dynamics of a geographically dispersed team is still to be fully elucidated, as the lack of synchronicity is likely to pose additional challenges, as well as offer opportunities.

Although virtual teams have minimal face-to-face contact, providing for face-to-face meetings is important (Siebdrat, Hoegl & Ernst 2009), characterised as ‘a heartbeat, rhythmically pumping new life into the team's processes, before members circulated to different parts of the world and task, returning again at a predictable pace’(Kelley 2001). Because of this some team members need to travel across multiple time zones, resulting in jet lag and impaired performance (Cohen & Gössling 2015), which is discussed in more detail in section 3.5.

The management of virtual teams has additional challenges, requiring greater management skills, and time zone differences compound this challenge. This review now discusses management of innovation in these teams.

3.3.5 Virtual Teams and Innovation

Virtual teams are essential for global innovation, and product launches typically use a global team to support their development (Harvey & Griffith 2007). As a result of innovation teams being dispersed, these teams are less hierarchical (DeCusatis 2008; Muethel, Gehrlein & Hoegl 2012), and can use talent without respect to temporal boundaries (Hertel & Orlikowski 2015).

Biotechnology is dependent on innovation (Hall & Bagchi-Sen 2002; Marot *et al.* 2005) and global (Madhok & Osegowitsch 2000), with the internet enabling the development of virtual biotechnology companies (Salazar, Hackney & Howells 2003) with more than half Australian biotechnology companies being virtual (Nicol, Liddicoat & Critchley 2013). Strategic alliances are vitally important in biotechnology, especially in Australia (Gilding 2008; Standing, Standing & Lin 2008), and to manage global projects, virtual teams are vital (Anantatmula & Thomas 2010).

3.3.6 Communication within Virtual Teams

A major challenge of virtual teams is communication, with language barriers, cultural barriers and time zone discontinuities, and the quality of communication within a team impacts performance. Gibson and Gibbs (2006) list dependence on electronic communication as a marker of virtuality for a team, and found a psychologically safe communication climate enhances performance, although the effects of virtuality on communication and team performance are complex (Marlow, Lacerenza & Salas 2016). Spontaneous communication within teams has been found to decrease conflict (Hinds & Mortensen 2005) and increase productivity (Hoegl, Weinkauf & Gemuenden 2004), while a reluctance to communicate has a negative effect on the team's performance (Charlier *et al.* 2016), and familiarity, particularly at a professional level, has been shown to enhance communication levels (Maynard *et al.* 2018). The importance of communication, as opposed to communication technology was highlighted in a study by Ferreira, de Lima and da Costa (2012), although communication technology is also important (Song & Song 2010).

While cultural diversity can have a positive influence on decision making, it can have a negative influence on communication (Shachaf 2008), as cross-cultural communication is inherently difficult (Daim *et al.* 2012; Vignovic & Thompson 2010), and cross-cultural training may be beneficial (Schmidtke & Cummings 2017).

As well as the challenges from cultural and language diversity, time zone disparity also makes communication more difficult, with team members having to work outside business hours to communicate (Chudoba *et al.* 2005), and the effect of time zone disparity can be offset by communication (Espinosa, Nan & Carmel 2015). One solution is for some team members to travel to meet face-to-face, which is important for virtual teams (Kelley 2001; Kirkman *et al.* 2004; Siebdrat, Hoegl & Ernst 2009). Regular face-to-face meetings have been likened to a rhythm of communication, like a heartbeat within a team (Maznevski & Chudoba 2000). Gibson and Cohen (2003, p. 18) reported on a global team where the travel budget was deemed important because 'relationships based in face-to-face tend to last'; communication technology and face-to-face contact are viewed as complementary (Aguilera 2008). This face-to-face interaction is particularly important for high-tech industries such as the biotechnology sector, where 'personal meetings are, however, still paramount to transfer knowledge-based resources' (Tolstoy & Agndal 2010). While face-to-face communication can enhance team performance, it comes at the cost of jet lag to travelling team members, impacting their performance.

3.3.7 Performance of Virtual Teams

Recommendations to improve the performance of virtual teams include conducting only a limited number of critical face-to-face meetings, uptake of communication technology, discussing cultural differences openly, establishing trust, and communicating frequently (Gibson & Cohen 2003, pp. 413-9) and with a shared team identity (Mortensen & Hinds 2001). Reliance on electronic communication can have drawbacks as well as advantages (Schaubroeck & Yu 2016). Alignment to group goals is important (Pearce & Conger 2003, p. 286) and has been shown to enhance virtual team performance (Muethel, Gehrlein & Hoegl 2012). Measuring a virtual team's performance can be difficult, but factors such as poor communication, language and cultural barriers, and lack of clarity around goals all have a negative impact (Ferreira, de Lima & da Costa 2012).

Virtual teams have additional challenges to collocated teams, and one of the major factors is the difference in time zones within these teams, which is now discussed.

3.3.8 Time Zone Differences within Virtual Teams

Time zone disparity is a measure of virtuality (Chudoba *et al.* 2005), increasing demands on the team (Kanthak & Hertel 2016) such as extended work hours and work overload due to asynchronous communication (Nurmi 2011), and structured communication process enable virtual teams to manage conflict better and increase performance (Montoya-Weiss, Massey & Song 2001). Virtual teams spanning multiple time zones also offers benefits, including being able to adopt a 'follow the sun' workflow (Carmel, Espinosa & Dubinsky 2010; Siebdrat, Hoegl

& Ernst 2009) which provides speed, as opposed to 'round the clock' workflow which allows full coverage (Carmel 2012). Having teams in multiple time zones enables 'continuous 24/7 productivity by using different time zones' (Dulebohn & Hoch 2017).

3.3.9 Summary of Virtual Teams

Virtual teams are necessary for global work, particularly for innovation. A disadvantage of virtual teams is the relative lack of face-to-face contact, which many teams overcome by having some members who travel. While this strategy facilitates communication, this travel poses problems in terms of jet lag. There are also challenges in terms of long work days and communication, although this is offset to some extent by the team being able to work around the clock.

Having discussed virtual teams and the impact of time zone differences within these teams, this review now turns to the psychology of their organisations.

3.4 Organisational Psychology

3.4.1 Introduction to Organisational Psychology

This section outlines organisational psychology, including the importance of organisational culture as well as the negative effects of working long hours and frequent business travel have on employees, and the importance of organisational support for members of globally dispersed innovation teams

Organisational culture 'can be used to describe attributes of an organisation related to its appearance, behaviour, and beliefs' (Kummerow, Ying & Kirby 2014, p. 5), describing organisational values (Zander, Jonsen & Mockaitis 2016), and is complex with many components (Powell, Lovallo & Caringal 2006) that have been defined as dimensions of organisational culture (van Den Berg & Wilderom 2004).

Dysfunctional organisational culture can manifest in a variety of ways, including a perfectionistic culture in which members work long hours (Balthazard, Cooke & Potter 2006), which can have negative implications for employees' wellbeing, as working long hours can potentially have severe and even fatal effects on employees' health (Goh *et al.* 2015; Pfeffer 2018).

Frequent business travel is also common with globally dispersed innovation teams (Siebdrat, Hoegl & Ernst 2009), and, as with long hours, frequent business travel can have negative effects on employees, including significant negative health outcomes, such as diabetes and cardiovascular disease (Burkholder *et al.* 2010).

Considering the potentially serious adverse outcomes for staff in globally dispersed innovation teams, particularly for those who travel internationally frequently, there is clearly a need for organisational support in globally dispersed teams, particularly for members who travel (Black & Jamieson 2007; Mäkelä & Kinnunen 2018). However, this organisational support is often missing for these team members, resulting in potentially negative health outcomes and impaired performance (Black & Jamieson 2007; Rundle 2018).

Organisational culture and values and the factors that influence them are now discussed.

3.4.2 Organisational Culture and Values

Organisational culture describes the internal attributes of an organisation (Kummerow, Ying & Kirby 2014, p. 5), with values that have been mapped (Bourne, Jenkins & Parry 2017; van Den Berg & Wilderom 2004). There is a complex interplay of cultural and organisational values (Zander, Jonsen & Mockaitis 2016), with organisational culture proposed to be a 'multi-level construct comprising artefacts, espoused beliefs and values and underlying assumptions' (Al Saifi 2015), often with paradoxes within organisational values that can be seen as complementary, being ‘both / and’ rather than ‘either / or’ (Bourne, Jenkins & Parry 2017). Knowledge management can have an impact on organisational culture (Corfield & Paton 2016), and knowledge management and organisational culture are closely linked (Al Saifi 2015).

Turning to the Australian context, the espoused values of organisations in Australia have been shown to differ to those in the United States, with a demand for a ‘fair and reasonable’ standard of living in Australia and a corresponding lowered tolerance for inequality (Kabanoff & Daly 2002). This indicates that organisational values are informed and influenced by national culture (Zander, Jonsen & Mockaitis 2016).

Organisational support is linked to organisational culture and has been shown to effectively address workaholism in employees (Mazzetti *et al.* 2017). However, this support has often been lacking for international business travellers (Black & Jamieson 2007; Ivancevich, Konopaske & Defrank 2003), and this lack of organisation support for business travellers is explored in a subsequent section of this thesis.

Having discussed organisational culture and values, the effect of working long hours and in dispersed teams is now explored.

3.4.3 Long hours and Working in Dispersed Teams

Because virtual teams are often dispersed across multiple time zones team members may need to work outside of normal business hours to accommodate this (Nurmi 2011), resulting in long working hours.

Long hours can be a symptom of a dysfunctional organisational culture (Balthazard, Cooke & Potter 2006) and toxic leadership (Berdahl *et al.* 2018). Long work hours are defined as working more than 61 hours a week (Brett & Stroh 2003) and can even be 70 or 120 hours a week (Hewlett & Luce 2006) resulting in a negative impact on health (Sparks *et al.* 1997; Spurgeon, Harrington & Cooper 1997), particularly on sleep (Åkerstedt *et al.* 2002). In the United States alone, it was found that more than 120,000 deaths per year and approximately 5%–8% of annual healthcare costs were due to workplace stress (Goh, Pfeffer & Zenios 2015), and that 'long work hours increase mortality by almost 20%' (Goh *et al.* 2015). The potential negative health effects of long work hours include cardiovascular disease, diabetes, anxiety, and depression (Åkerstedt *et al.* 2002; Bannai & Tamakoshi 2014; Ganster, Rosen & Fisher 2018; Kivimäki *et al.* 2015; Rundle, Revenson & Friedman 2018; van der Hulst 2003), and the health consequences of employees working long hours can be severe (Pfeffer 2018).

Communication technology can have an impact on work-life balance, both positive and negative. Business travellers are more readily able to connect with family members at home (Ladkin *et al.* 2016), but this can also result in a blurring of work hours and personal hours (Köffer *et al.* 2015; Kossek 2016), resulting in an 'always available' culture which leads to a variety of dysfunctional behaviours such as prioritising work over their personal life or become disengaged (Reid & Ramarajan 2016). International business travel has a negative effect on the family life of business travellers (Saarenpää 2016), and can even result in negative health outcomes or stress for family members of business travellers (Dimberg *et al.* 2002; Espino *et al.* 2002).

There is also a gender component to working long hours: companies that work across multiple time zones often require greater commitment from their employees in terms of working long or odd hours; if women are perceived to be less flexible in their working hours, there is an increased gender wage gap (Bøler, Javorcik & Ulltveit-Moe 2018).

Workers who work long hours can experience disruption to their family life or social activities (Harrington 2001), with family members only having minimal contact (Hewlett & Luce 2006).

Working in teams across multiple time zones often results in working odd or long hours (Nurmi 2011) and can result in significant health challenges for workers (Pfeffer 2018). While technology can assist these workers, it can also disrupt family and social life. This review now turns to another challenge of workers in dispersed teams, namely jet lag.

3.4.4 Frequent Business Travel

As discussed previously, for globally dispersed teams face-to-face meetings are important (Siebdrat, Hoegl & Ernst 2009), likened to a 'heartbeat' of communication (Kelley 2001), and travel to these meetings is likely to result in jet lag (Sack 2010). In a dysfunctional organisational culture, staff are not supported when they travel, and lack of sleep is the cultural norm (Czeisler & Fryer 2006). Organisations may not necessarily perceive the importance of supporting their employees who travel (Ivancevich, Konopaske & Defrank 2003). There are a considerable number of physical challenges resulting from jet lag. Apart from the obvious sleep deprivation, chronic diseases such as diabetes and cardiovascular disease can also result from the chronic sleep deprivation associated with jet lag (Burkholder *et al.* 2010). There is also psychological stress from frequent long-distance business travel due to as concerns regarding the wellbeing of the traveller's family (Striker *et al.* 1999), as not only is the business traveller stressed, but so are their family members (Dimberg *et al.* 2002; Espino *et al.* 2002). However, while there is frequently stress from business travel, there can also be a positive stimulation for some travellers (Gustafson 2014).

Significantly for business travellers, jet lag can result in cognitive deficits (Burkholder *et al.* 2010; Cho *et al.* 2000; Scott, McNaughton & Polman 2006), impairing performance (Helfat &

Peteraf 2014). When the cultural norm for business travellers is to be 'conducting business in a cloud of caffeinated jet lag' (Czeisler & Fryer 2006), doing business while affected by jet lag can have a negative impact on cognitive function and performance.

Apart from jet lag, there are other significant issues for travellers who frequently travel internationally for business. Stress, poor food choices and lack of exercise due to travelling can result in long-term health problems (Rundle 2018), with emotional exhaustion being reported in a study of 133 frequent business travellers (Niessen *et al.* 2018), as well as loneliness and a sense of loss of connection from family (Baker & Ciuk 2015).

The effect of jet lag is not only experienced by the frequent business traveller, but physical and psychological stress can also affect their families (Dimberg *et al.* 2002; Espino *et al.* 2002), indicating a need for support for these frequent travellers and their families. However, despite the value that business travellers provide to their firms (Welch, Welch & Worm 2007), for most business travellers there is a lack of support from their organisations (Baker & Ciuk 2015; Black & Jamieson 2007; Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007). This lack of organisational support for these workers is now explored further.

3.4.5 Organisational Support

Organisations with employees who frequently travel for business should focus beyond cost for travel and expand their support for staff who travel for business (Ivancevich, Konopaske & Defrank 2003). Organisational support has been shown to have a moderating influence on employees' workaholism due to presenteeism in a study of over a thousand white-collar employees, enabling them to better balance their work and family commitments (Mazzetti *et al.* 2017). However, this organisational support has not always been forthcoming. Black and Jamieson (2007) interviewed 25 frequent business travellers in depth, and in the words of one of the study participants, ‘if you don’t balance your life yourself there is no warm fuzzy person [in the company] going to come to you and say, Gee, you’ve been working too hard’, implying a need for proactive intervention by organisations that have employees who frequently travel.

One simple strategy that organisations can execute is to alleviate the stress of business travel is to ensure that accommodation for business travellers includes a well-equipped gymnasium or access to gym and health club chains (Rundle 2018), as a lack of exercise has been reported in international business travellers, which is linked to depression (Black & Jamieson 2007). Similarly, ensuring that business travellers have access to healthy eating options available when they travel for business can assist with improved health outcomes (Rundle 2018).

Stress has been associated with business travel (Beaverstock *et al.* 2009; Chen 2017; Ivancevich, Konopaske & Defrank 2003), and having a well formulated stress policy at an organisational level could be beneficial to frequent business travellers (Baker & Ciuk 2015). Additionally, training staff in a variety of stress management techniques with mindfulness-based stress reduction and cognitive behavioural therapy have been shown effective for managing workplace stress for staff who frequently travel (Rundle 2018).

Having the human resources department develop policy to support staff who travel frequently in a systematic manner, with clearly defined policies, is preferable to individual departments having an *ad hoc* approach to managing their business travellers (Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007).

Having discussed the need for organisational support for employees who frequently travel internationally on business, the points raised in this section on organisational psychology are now summarised.

3.4.6 *Summary of Organisational Psychology*

Organisational culture has an impact on an employee's wellbeing, with issues such as overly long working hours, work-life balance and jet lag all having a negative effect on performance. Long hours, which are frequently reported in members of global teams (Nurmi 2011), can result in substantially negative health outcomes including cardiovascular disease, diabetes, anxiety, and depression (Bannai & Tamakoshi 2014; Ganster, Rosen & Fisher 2018; Kivimäki *et al.* 2015; Rundle, Revenson & Friedman 2018), as can frequent business travel (Niessen *et al.* 2018; Rundle 2018). However, the most significant finding of the review of the literature around organisational psychology is the almost complete lack of organisational support for workers in globally dispersed innovation teams, particularly for those who frequently travel internationally across multiple time zones (Black & Jamieson 2007), despite the substantial health risks to these workers.

The biological mechanism of performance impairment due to jet lag is now discussed.

3.5 Chronobiology

3.5.1 *Introduction to Chronobiology*

Humans, like other mammals, operate according to a 'body clock', referred to as the circadian rhythm (Sack 2010). When travellers cross three or more time zones the circadian rhythm is disrupted, resulting in jet lag (Waterhouse *et al.* 2007). This section discusses circadian rhythm and jet lag in more detail.

3.5.2 *The Human Circadian Rhythm*

This circadian rhythm is responsible for biological timekeeping throughout the body and is encoded genetically (Masri & Sassone-Corsi 2012) and can be measured by biological factors such as core body temperature or secretion of melatonin (Schmidt *et al.* 2007). This circadian rhythm is coordinated by a part of the brain called the suprachiasmatic nucleus (Antle & Silver 2005; Aton & Herzog 2005) which secretes the hormone melatonin to regulate the circadian rhythm. Light, particularly blue light, affects the circadian rhythm (Kervezee *et al.* 2019) and suppresses melatonin levels (Revell *et al.* 2006; Wright & Lack 2001), with a degree of genetic sensitivity to this effect of blue light on the circadian rhythm (Chellappa *et al.* 2012). This circadian rhythm is thought to be modulated to some extent by the element lithium (Moreira & Geoffroy 2016).

Most humans' body clocks do not run to a precise 24-hour day (Horne & Östberg 1975), and they are synchronised by light. There are specific light receptors in the eye cells acting as timekeepers for the circadian rhythm (Berson, Dunn & Takao 2002; Green & Besharse 2004; Hattar *et al.* 2002), enabling it to adjust according to light received by the eye (Scheer *et al.* 2007). A functional circadian rhythm is important for good health (Lucassen *et al.* 2016; McKenna *et al.* 2018; Roenneberg & Merrow 2016), particularly cognitive function (Ramkisoensing & Meijer 2015), and disruptions to the circadian rhythm can contribute to a number of diseases including psychiatric disorders, obesity, diabetes, cardiac disease, hypertension and cancer (Hassan *et al.* 2018; Lewis, Foster & Erren 2018; Smolensky *et al.* 2016). Younger adults appear to be at greater risk of impaired performance from circadian disruption than older adults (Zitting *et al.* 2018).

Sleep is vital for brain health (Xie *et al.* 2013) and chronic disruption of sleep 'may lead to metabolic, reproductive, sleep, and mood disorders' (Bedrosian, Fonken & Nelson 2016). Importantly for business travellers, sleep deprivation has a negative impact on memory (Occhionero, Cicogna & Esposito 2017), cognitive function (Cho *et al.* 2000; Scott, McNaughton & Polman 2006), decision making (Alkozei *et al.* 2018), increased risk-taking

(Maric *et al.* 2017) and lack of ability to read others' emotions (Guadagni *et al.* 2014; van der Helm, Gujar & Walker 2010). These effects of sleep deprivation worsen if it is chronic (Cohen *et al.* 2010) and are linked to the development of Alzheimer's disease (Kent & Mistlberger 2017) and cancer (Blask 2009; Erren *et al.* 2016; Fu & Kettner 2013; Fu, Zhao & Evans 2016; Hu *et al.* 2013; Huang, Fu & Bu 2011; Karoutsos, Karoutsos & Karoutsou 2017), including breast cancer (Stevens 2005). The economic cost to the Australian economy of inadequate sleep is substantial, with an estimated financial cost of US$17.88 billion and nonfinancial cost of US$27.33 billion annually (Hillman *et al.* 2018).

Everyone has a chronotype, which is a propensity to be more active and alert in the morning, evening or the middle of the day. People who are most active in the evening may experience difficulties concentrating earlier in the day in a standard 9-to-5 workday (Facer-Childs *et al.* 2019). There is a great deal of diversity in chronotypes (Horne & Östberg 1975; Kerkhof & Van Dongen 1996) which are age and sex-related (Fischer *et al.* 2017; Roenneberg 2012, p. 197) and modulated by season of birth (Natale & Adan 1999), and there are different cognitive function patterns for different chronotypes, each with differences found in brain architecture (Rosenberg *et al.* 2018; Schmidt *et al.* 2015). This diversity of chronotypes is genetically-based, with variations on the gene *PER3* on chromosome 1 determining whether people are more alert in the morning ('morningness') or in the evening ('eveningness') (Dijk & Archer 2010; Hida *et al.* 2014; Viola *et al.* 2007), with a sequence of 18 amino acids within this gene being crucial in determining chronotype (Archer *et al.* 2003; Archer *et al.* 2018). In a study of 63 winter Canadian National Team athletes showed a greater tendency towards morningness in these elite athletes (Bender, Van Dongen & Samuels 2018). Having teams with chronotype diversity, where team members vary in their alertness at different times of day can have both positive and negative effects on the team's productivity, depending on recognition of the chronotype diversity and structuring work accordingly (Volk *et al.* 2017).

Caffeine has been shown to lengthen the circadian rhythm (Burke *et al.* 2015), potentially making it useful for travellers flying westward but not eastward and could cause nocturnal wakefulness in patients with jet lag (Auger & Morgenthaler 2009). Tea may have a beneficial effect on restoring the circadian rhythm after long distance travel (Qi *et al.* 2017), although others warn against its use (Herxheimer & Waterhouse 2003).

There are advantages and disadvantages to each of the different chronotypes: for evening types, creative thinking (Giampietro & Cavallera 2007), and cognitive function when forced to stay awake (Barclay & Myachykov 2016), although evening types are more prone to 'social jet lag' (Wittmann *et al.* 2006), sleep deprivation (Roenneberg, Wirz-Justice & Merrow 2003), and health issues (Haraszti *et al.* 2014), particularly for younger people and women (Fabbian *et al.* 2016). Meetings at odd hours of the day can also cause 'social jet lag', resulting in circadian misalignment like jet lag (Reid & Abbott 2015; Wittmann *et al.* 2006).

A person's chronotype is individual with some input from age, sex, and birth month, genetically encoded and influences their circadian rhythm which is moderated by light, typically sunlight. Disruption of this circadian rhythm due to travelling and crossing multiple time zones results in jet lag, which is now discussed.

3.5.3 Jet Lag

With the jet age in the late 1950s rapid transport around the globe became possible, resulting in the likelihood of jet lag (Balmer, Nevill & Williams 2001), a condition which typically occurs when a person crosses three or more time zones (Waterhouse *et al.* 2007). This is due to the body clock being wrongly timed (Sharma, Tiwari & Singaravel 2016). Symptoms of jet lag are mainly daytime sleepiness and night-time wakefulness, but can also include mood disorder, impaired physical and cognitive performance, and gastrointestinal upset (Sack 2010). Cognitive function is dependent on the circadian rhythm (Schmidt *et al.* 2007) and is particularly relevant for business travellers (Czeisler & Fryer 2006) as it can adversely affect performance (Coste & Lagarde 2009). Even the modest effect altering the time an hour due to daylight saving has an effect on cognitive function (Schaffner *et al.* 2018). Jet lag is part of a broader disorientation caused by travel (Anderson 2015), and is distinct from travel fatigue, which can occur from travel that does not involve crossing multiple time zones (Fowler *et al.* 2015). This impaired cognitive function resulting from jet lag can cause mistakes and accidents (Åkerstedt 2007), and chronic jet lag produces cognitive deficits for the frequent traveller (Cho 2001). An increased rate of illness has been reported for travellers who cross more than five time zones, which returns to the baseline on return (Schwellnus *et al.* 2012).

Some individuals travel across multiple time zones better than others (Ruscitto & Ellis 2007; Waterhouse *et al.* 2007), and the ability to travel across time zones successfully is dependent on coping with physical and psychological stresses (Izadi & Ahmadinejad 2015); this is thought to be due to genetic variation in the human gene *PER3* (Arendt 2009).

Jet lag also has a directional component, with flying west associated with less jet lag than east (Flower, Irvine & Folkard 2003; Lemmer *et al.* 2002; Monk *et al.* 2000; Waterhouse *et al.* 2007), although this is dependent on the circadian rhythm of the individual traveller (Diekman & Bose 2017; Facer-Childs & Brandstaetter 2015), with some morning types finding eastward travel easier (Sack 2010).

Many studies have been conducted on jet lag using standardised measures for jet lag, including the Charité Scale (Becker, Penzel & Fietze 2015b), Columbia Jet Lag Scale (Spitzer *et* *al.* 1999), and Liverpool Jet Lag Questionnaire (Waterhouse *et al.* 2002). Most of the studies in jet lag have been conducted in either athletes or healthy volunteers, with very few studies focusing on the needs of business travellers. Similarly, while sleep patterns, biological markers, mood and physical effect (such as grip strength or heart rate) have been frequently evaluated, the effect of jet lag on cognitive function has been often overlooked, with only a relatively small proportion of studies in jet lag specifically addressing the effect on cognitive function, which is important for business travellers (Czeisler & Fryer 2006). Instead, most studies in jet lag have used either healthy volunteers or athletes, with a heavy emphasis on biological markers rather than cognitive impairment. A comprehensive list of studies in jet lag is given in Table 1 listing the authors, parameters measured and trial population, and this table demonstrates the relative lack of research with business travellers and measuring cognitive function.

Table 1: Studies in Jet Lag

Study	Physical Effect	Cognitive Effect	Biological Markers	Mood Effect	Sleep Effect	Sample Size	Population Studied
Agostino, Plano and Golombek (2007)[1]	✓	no	✓	no	✓	Not stated [(1)]	Hamsters
Arendt *et al.* (1987)	no	✓	✓	✓	✓	17	Healthy volunteers
Arendt and Aldhous (1988)	no	no	✓	no	no	52	Long-distance travellers
Becker, Penzel and Fietze (2015a)	no	✓	✓	✓	✓	89	Long-distance travellers
Belcaro *et al.* (2008)[2] (study 1)	no	✓	✓	✓	✓	68	Long-distance travellers
Belcaro *et al.* (2008)[2] (study 2)	no	✓	✓	✓	✓	65	Long-distance travellers
Boulos *et al.* (2002)	✓	no	✓	✓	✓	20	Healthy volunteers
Caldwell, Caldwell and Darlington (2003)	✓	no	no	✓	✓	28	Military pilots
Cho *et al.* (2000)	no	✓	✓	no	no	62	Airline cabin crew
Claustrat *et al.* (1992)	no	✓	no	✓	✓	30	Business travellers
Cole and Kripke (1989)	no	no	no	no	✓	19	Healthy volunteers
Eastman *et al.* (2005)	no	no	✓	no	✓	26	Healthy volunteers
Edwards *et al.* (2000)	✓	✓	✓	no	✓	31	Business travellers
Fowler *et al.* (2014)	✓	no	✓	✓	✓	13	Healthy male volunteers
Fowler *et al.* (2016)	no	no	✓	no	✓	18	Athletes
Hill *et al.* (1993)[3] (study 1)	✓	no	no	✓	✓	7	Athletes
Hill *et al.* (1993)[3] (study 2)	✓	no	no	✓	no	10	Healthy volunteers
Hill *et al.* (1993)[3] (study 3)	✓	no	no	no	no	9	Healthy volunteers

Study	Physical Effect	Cognitive Effect	Biological Markers	Mood Effect	Sleep Effect	Sample Size	Population Studied
Hoshikawa, Uchida and Dohi (2018)	no	no	no	no	✓	2	Athletes
Jurvelin, Jokelainen and Takala (2015)	no	no	no	✓	✓	55	Healthy volunteers
Katz *et al.* (2002)	no	no	no	✓	No	152	Foreign tourists
Klein and Wegmann (1974)	no	no	no	✓	✓	8	Students
Lahti *et al.* (2007)	no	no	no	no	✓	15	Airline cabin crew
Lemmer *et al.* (2002)	✓	no	✓	no	✓	19	Athletes
Monk *et al.* (1993)	no	no	✓	✓	✓	25	Healthy elderly volunteers
Monk *et al.* (2000)	no	no	✓	no	✓	20	Healthy elderly volunteers
Montaruli *et al.* (2009)	no	no	no	no	✓	18	Athletes
Murphy *et al.* (2007) [4]	no	no	✓	no	No	6 [(4)]	Horses
Nickelsen, Lang and Bergau (1991)	no	no	✓	no	No	36	Long-distance travellers
Paul *et al.* (2009)[2] (study 1)	✓	✓	✓	no	No	14	Healthy volunteers
Paul *et al.* (2009)[2] (study 2)	✓	✓	✓	no	No	13	Healthy volunteers
Paul *et al.* (2009)[2] (study 3)	✓	✓	✓	no	No	10	Healthy volunteers
Petrie *et al.* (1989)	no	no	✓	✓	✓	20	Healthy volunteers
Petrie *et al.* (1993)	no	no	✓	✓	✓	52	Airline cabin crew
Reynolds and Montgomery (2002)	✓	✓	no	✓	✓	186	Soldiers
Rosenberg *et al.* (2010)	✓	no	no	no	✓	427	Adults with a history of jet lag
Ruscitto and Ogden (2017)	✓	✓	no	✓	✓	60	Airline cabin crew

Study	Physical Effect	Cognitive Effect	Biological Markers	Mood Effect	Sleep Effect	Sample Size	Population Studied
Sasaki *et al.* (1989)	no	no	no	no	✓	4	Healthy volunteers
Shiota, Sudou and Ohshima (1996)	no	no	✓	no	no	10	Airline cabin crew
Sieberichs and Kluge (2018)	✓	✓	no	✓	✓	106	Pilots
Spitzer *et al.* (1999)	no	no	✓	✓	✓	257	Physicians
Straub *et al.* (2001)	✓	no	no	✓	✓	15	Athletes
Suhner, AG *et al.* (2001)	no	no	✓	✓	✓	9	Healthy volunteers
Suhner *et al.* (1998)	no	no	no	✓	✓	320	Healthy volunteers
Suhner, Andrea *et al.* (2001)	no	no	✓	✓	✓	137	Healthy volunteers
Thompson *et al.* (2013)	✓	✓	no	✓	✓	20	Athletes
Tortonese *et al.* (2011)[4]	✓	no	✓	no	no	7[(4)]	Horses
Waterhouse *et al.* (2000)	✓	no	no	✓	✓	39	Athletes & sport administrators
Waterhouse *et al.* (2002)	no	no	✓	no	✓	85	Athletes
Zerbini, Kantermann and Merrow (2018)[2]	no	no	no	no	✓	38	Healthy volunteers
Zerbini, Kantermann and Merrow (2018)[2]	no	no	no	no	✓	38	Healthy volunteers

Notes:

1. This study was conducted in hamsters
2. Belcaro *et al.* (2008) and Zerbini, Kantermann and Merrow (2018) include two studies
3. Hill *et al.* (1993) and Paul *et al.* (2009) each include three studies
4. These studies were conducted in horses

Table 2 shows that very few business travellers have been researched in studies investigating the human response to jet lag, and the majority of research was conducted in either healthy volunteers or athletes. It has been noted that the translation of jet lag research from animal studies to human clinical trials and effective jet lag research is very poor (Atkinson *et al.* 2014). Business travellers have different needs and are particularly dependent on having good cognitive function when they travel (Czeisler & Fryer 2006). Business travellers make up a large proportion of flyers and have a disproportionately high spend due to the use of premium flight classes, so it seems there is a lack of research in this subset of travellers.

Having discussed jet lag with a selective focus on business travellers, this review now discusses methods used to mitigate its effects.

3.5.4 Jet Lag Mitigation

There are a variety of methods to treat jet lag: light therapy, melatonin, wakefulness agents, hypnotic agents, caffeine, diet, adjusting the schedule to the new time zone before travelling, or remaining on the schedule of the time zone of origin (Cingi, Emre & Muluk 2018; Eastman & Burgess 2009; Sack 2010; Zee & Goldstein 2010), many of which do not include drugs (Bin, Postnova & Cistulli 2019). These options and their effectiveness are now discussed.

The human circadian rhythm is sensitive to light (Emens & Burgess 2018), as the human circadian rhythm is not exactly 24 hours in length, and needs to be reset daily (Duffy & Czeisler 2009), and a large number of studies have investigated the use of light therapy for jet lag (Phipps-Nelson *et al.* 2009; Regente *et al.* 2017). Light at the blue end of the spectrum is particularly useful for resetting the body clock (Revell *et al.* 2006; Smith & Eastman 2009; Smith, Revell & Eastman 2009; Warman *et al.* 2003), with the regulating pigment melanopsin maximally sensitive to wavelengths of 479 nanometres, corresponding to blue-green light

(Bailes & Lucas 2013). Red light is less effective at adjusting the body clock (Boulos *et al.* 2002; Hanifin *et al.* 2006) and may even act as a sedative (van der Meijden *et al.* 2018). There are now blue-green light devices for travellers to offset jet lag (Lau, Lovato & Lack 2018; Lovato & Lack 2015), and these have been used by Olympic athletes (Rosa *et al.* 2018). A recent variation of light therapy has been the use of a novel and atypical 24 hour cycle with short bursts of light and darkness to facilitate resetting of the circadian rhythm more rapidly (Noguchi *et al.* 2018). Light therapy is not useful during daytime, but only at night (Segal *et al.* 2016), while reducing blue light in the evening using blue-light-blocking glasses has been shown to enhance sleep (Zerbini, Kantermann & Merrow 2018).

There are various pharmacological agents used to ameliorate the symptoms of jet lag, including melatonin, sedatives, wakefulness agents and caffeine (Beaumont *et al.* 2004; Choy & Salbu 2011; Sack 2010; Suhner, Andrea *et al.* 2001), although in a survey of 629 travellers were recruited from Saudi Arabia the most commonly used medications were paracetamol, ibuprofen and antihistamines, which are all available over the counter (Alnaim 2017). There are also non-pharmacological methods commonly used to mitigate jet lag symptoms, including flying business class, diet, exercise, napping, and scheduling work in line with the new time zone (Sack 2010; Herxheimer & Waterhouse 2003; Waterhouse *et al.* 2007; Zerbini, Kantermann & Merrow 2018).

Melatonin is the naturally-occurring hormone that regulates the circadian rhythm (Herxheimer & Petrie 2002; Lewy, Ahmed & Sack 1995), and pharmaceutical melatonin has been found to be effective in preventing or reducing jet lag (Herxheimer & Petrie 2002). The safety and effectiveness of melatonin has been borne out in several studies (Claustrat *et al.* 1992; Petrie *et al.* 1989; Sletten *et al.* 2018; Suhner, Andrea *et al.* 2001). Melatonin is currently available only on prescription in Australia although it is available over the counter in the United States and parts of Europe (Therapeutic Goods Administration 2017), and approximately 2% of American adults use melatonin supplementation for sleep (Bliwise & Ansari 2007). Prolonged release melatonin and melatonin analogues are available, such as ramelteon and tasimelteon (Burgess & Emens 2018; Choy & Salbu 2011; Hoshikawa, Uchida & Dohi 2018). However, melatonin has not been found useful to enhance physical performance in a sport context (Farjallah *et al.* 2018; López-Flores *et al.* 2018), and in subjects who 'after arrival, followed a busy schedule which resulted in frequent and erratic exposure to daylight, melatonin had no benefit in alleviating jet-lag' (Edwards *et al.* 2000), indicating that subjects who are overly busy in their business travel (Czeisler & Fryer 2006) may not receive the full benefit from melatonin treatment.

Sedatives are also used in the treatment of jet lag, including benzodiazepines such as temazepam (Reilly, Atkinson & Budgett 2001; Sack 2009), and other sedatives such as diphenhydramine (Choy & Salbu 2011), zolpidem (Choy & Salbu 2011; Herxheimer & Petrie 2002; Suhner, Andrea *et al.* 2001) and zopiclone (Herxheimer & Petrie 2002; Sack 2009), but unlike melatonin, sedatives do not have a direct effect on the circadian rhythm.

Wakefulness agents have also been used for jet lag (Sack 2010), with modafinil and adrafinil used to treat fatigue from with jet lag successfully (Coste & Lagarde 2009), although modafinil is only moderately effective for shift work sleep disorder (Czeisler *et al.* 2005). Armodafinil was found to be effective in a trial with 427 participants who flew eastward through six time zones (Rosenberg *et al.* 2010), and dextroamphetamine has been used for fatigue in military pilots (Caldwell, Caldwell & Darlington 2003). However, there are warnings against the prolonged use of wakefulness agents in the treatment of jet lag (Coste & Lagarde 2009), and while there is moderate benefit in the use of these agents, it has a limited place in alleviating jet lag.

Caffeine is a wakefulness agent that is readily available over the counter (Dudley *et al.* 2017) as well as in tea, coffee, cola and energy drinks (Burdan 2015; Graham 1978; Mitchell *et al.* 2014), and is used to counteract neurobehavioral impairment from lack of sleep (Hansen *et al.* 2018). Caffeine appears to have a direct effect on the circadian rhythm, lengthening it by approximately 40 minutes (Burke *et al.* 2015). Caffeine can be useful for travellers to stay awake and alert for short periods of time (Coste & Lagarde 2009), although its effect on the circadian rhythm may make it more useful for westward flights than for eastward ones (Burke *et al.* 2015), as the evidence of benefit for eastward flights appears to be mixed (Beaumont *et al.* 2004).

Sildenafil (Viagra) was used to treat simulated jet lag in hamsters, and found useful when circadian cycles was advanced by six hours (equivalent to flying eastward across six time zones) but not useful for cycle delay (equivalent to flying westward) (Agostino, Plano & Golombek 2007). While it has been suggested that men who travel frequently and use sildenafil may experience a stabilising effect on their circadian rhythm (Seppa 2007, p. 324), this effect has not been verified in humans, and is likely to only work for eastbound flights.

Flying business class has been used by some travellers to ameliorate the worst effects of jet lag, and it has been recommended as a way of minimising the impact of jet lag (Sack 2010), although the benefit of flying business class has been questioned. Airlines typically receive most of their profits from travellers flying first and business class (Gillen & Lall 2004), and there are pressures for business travellers to increasingly fly economy (Mason 2000, 2001, 2002, 2005). There are currently no data to indicate that business class has a beneficial effect on jet lag. One key study on the benefit of flying business class investigated possible effects on deep vein thrombosis (Jacobson *et al.* 2003) and did not detect a positive effect of flying business class.

Diet has been used to ameliorate jet lag with limited effect. Eating fibre (for example, apples) and water or juice rather than tea or coffee has been suggested (Herxheimer & Waterhouse 2003) but this is to minimise caffeine intake and avoid constipation. The timing of meals may be particularly important, with small meals better tolerated than large ones (Halson, Burke & Pearce 2018). Sixty long-haul airline crew took part in a trial where one group was randomised to eat regular meals on days off, which resulted in an alleviation of the symptoms of jet lag (Ruscitto & Ogden 2017). A trial of the Argonne diet, which 'alternates days of 'feasting' on high-protein breakfasts and lunches and high-carbohydrate dinners with days of 'fasting', defined as eating small, low-calorie meals' has been tried with the United States military (Reynolds & Montgomery 2002), with animal studies showing that high-calorie, high-fat diets can impair circadian adaptation (Leatherwood & Dragoo 2013), but generally there is little evidence that diet affects the circadian rhythm (Waterhouse *et al.* 2007).

Exercise, like diet, has minimal effect on alleviating jet lag (Waterhouse *et al.* 2007) although physical exercise has been suggested for patients with disturbed circadian rhythms (Vitale *et al.* 2018). One small study found exercise at night time delayed the production of melatonin, which is responsible for sleep (van Reeth *et al.* 1994), although in practical terms the majority of travellers are not able to achieve the substantial level of activity sufficient to alter the body clock (Atkinson *et al.* 2007).

Napping has been used to treat jet lag, and its efficacy was assessed in a survey of 106 pilots, finding a degree of correlation between napping and improved sleep quality (Sieberichs & Kluge 2018).

A simple technique to reduce jet lag is scheduling the working day in line with the new time zone several days beforehand (Zerbini, Kantermann & Merrow 2018), and a timetable scheduling sleep before long distance travel has been prepared by Revell and Eastman (2005). This is used in sport medicine (Samuels 2012) but can be used by other travellers. Scheduling is an effective therapy in combination with other therapies. The greater the number the time zones to be crossed, the longer the time required to adjust, with eastward journeys requiring more time to adjust than westward ones (Markwell & McLellan 2019).

Lastly, for short journeys of two or three days it may not be worthwhile adjusting the circadian rhythm (Arendt 2009), a strategy commonly used by air crew (Lowden & Åkerstedt 1998) who experience circadian disruption (Perrin *et al.* 2018). A recent case study of a 47-year-old man who flew on 16 international flights (191 hours of flying over a distance of 159,736 kilometres) over 12 consecutive days while maintaining a sleep-wake schedule based on Sydney, Australia time found that 'despite repeated changes in transmeridian travel direction and flight duration, the participant was able to maintain a stable sleep schedule aligned with the Sydney night', with only minor circadian misalignment, which was most likely due to spending time in transit in overseas airports (Gordon *et al.* 2018). Given the success of this approach under circumstances involving such extreme travel (equivalent to circumnavigating the earth four times), it would seem reasonably likely to be beneficial for short haul journeys.

In summary, there are several therapies that can alleviate jet lag, including light therapy, melatonin, sedatives, wakefulness agents and scheduling are all useful. Caffeine can be problematic, diet and exercise have minimal impact on jet lag, and scheduling activities to the new time zone and, not adjusting to the new time zone may also be useful strategies. This review now turns to the effect jet lag can have on the performance of travellers.

3.5.5 Jet Lag and Performance

Given severity of jet lag, it would seem reasonable that jet lag has a negative effect of performance, as described by Czeisler and Fryer (2006). Physical effects of jet lag include daytime fatigue and night-time insomnia (Sack 2010) and gastrointestinal disturbances (Drake & Wright 2011), and obesity (Gerhart-Hines & Lazar 2015). However, jet lag also has negative cognitive effects (Sack 2010), especially chronic jet lag (Cho 2001), due to effects on the brain (McEwen & Karatsoreos 2015). The impact of jet lag on performance is discussed in more detail in section 3.6.

3.5.6 Other Hazards of Flying

While jet lag is a significant issue for travellers, they also face other hazards, such as stress, poor dietary habits, and lack of exercise due to business travel (Rundle 2018). Chronic medical conditions can be exacerbated by airline travel due to decreased cabin pressure, cosmic radiation and cabin air quality (Silverman & Gendreau 2008), motion sickness (DeHart 2003), and business travellers have a higher rate of medical claims, especially for infectious diseases (Liese *et al.* 1997). In a retrospective study using data from 18,328 employees, higher levels of business travel had negative effects, including higher rates of smoking, higher alcohol intake, more difficulty sleeping, being sedentary, and reported anxiety or depression (Rundle 2018).

Transmission of infectious diseases in aircraft is likely, with air travel referred to as 'a lottery ticket for an upper respiratory infection' (Ozonoff & Pepper 2005), including avian flu (Tuncer

& Le 2014), severe acute respiratory syndrome or SARS (Mangili & Gendreau 2005), swine flu (Warren, Bell & Budd 2010), measles (Edelson 2012; Jost *et al.* 2015; Nelson *et al.* 2013), tuberculosis and influenza (DeHart 2003), and Ebola (Dowell *et al.* 1999). Disturbingly, 'quarantine and travel restrictions are unlikely to be very effective in preventing disease spread' (Huizer *et al.* 2015) and there is contradictory and confusing public health guidance around airline-related diseases (Grout *et al.* 2017) in a rapidly changing landscape (Budd, Morag & Brown 2009).

Deep vein thrombosis has emerged as a significant hazard of flying, with approximately one in 100 study subjects developing symptomless deep vein thrombosis in a clinical trial (Scurr *et al.* 2001; Silverman & Gendreau 2008), with no benefit reported from business class (Jacobson *et al.* 2003). Remaining seated for the duration of the flight increases the risk of developing deep vein thrombosis (Brundrett 2001). In an analysis of medical data of employees, those who travelled frequently for business were more likely to smoke, have alcohol dependence, have trouble sleeping, be sedentary or have anxiety or depression (Rundle, Revenson & Friedman 2018). Another issue for some travellers is the challenge of flying long distance with type I diabetes (Pinsker *et al.* 2017). Other hazards of flying include air rage (DeCelles & Norton 2016) and stress due to the threat of hijacking, acts of terror (DeHart 2003), and plane crashes (Evershed 2014).

Rarely, psychosis has been triggered by travel that involved crossing multiple time zones (Airault & Valk 2018; Katz 2011; Katz *et al.* 2001; Katz *et al.* 2002), with depression linked to westbound flights, and mania associated with eastbound flights (Jauhar & Weller 1982; Young 1995).

Additionally, a sense of disorientation independent of jet lag has been reported by a number of business travellers (Scurr *et al.* 2001), as well as difficulties in personal relationships from frequent travel (Anderson 2015; Cohen & Gössling 2015). The hazards of long distance travel include physical, cognitive and emotional challenges for those who travel frequently.

3.5.7 Summary of Chronobiology

Jet lag can be successfully managed with proven therapies which have been evaluated in clinical trials, although very few of these studies have been conducted with business travellers. Business travellers have different needs, particularly effective cognitive function. This review now turns to the various aspects of performance that are affected when a team is dispersed across multiple time zones.

3.6 Performance

This review now discusses performance and its measurements, examining individual, team and firm levels of performance.

3.6.1 Individual Performance

The main symptom of jet lag is fatigue associated with circadian rhythm disruption and resulting sleep deprivation (Coste & Lagarde 2009), with other symptoms including cognitive impairment and gastrointestinal disturbances (Sack 2010). Sleep disturbance can itself impair cognitive function (Åkerstedt 2007; DeSanctis 2017), with attention, memory, judgment, decision making, innovative thinking, risk-taking and higher cognitive functions all disturbed by lack of sleep (Goel *et al.* 2009; Harrison & Horne 1999; Kelley, Evans & Kelley 2018; Killgore & Weber 2014). Moderate sleep deprivation is similar to alcohol intoxication in its effect on cognition (Williamson & Feyer 2000). Focus is notably impaired due to jet lag (DeSanctis 2017), which is necessary for peak performance (Privette & Brundrick 1991). However, business culture typically does not support workers travelling across multiple time zones well (Czeisler & Fryer 2006). Six different types of stress have been identified for business travellers: 'travel arrangements, hotel/airline preferences, travel inconvenience, difficulty maintaining a healthy lifestyle, destination concerns, and work/personal life' (Chen 2017).

While the business travel experience can include moments of relaxation (Unger, Uriely & Fuchs 2016), there is also stress associated with travel (Beaverstock *et al.* 2009; Chen 2017; Ivancevich, Konopaske & Defrank 2003), particularly time away from the family home (Gustafson 2012b). Jet lag and absence from home contribute to negative associations with business travel.

The effect on the performance of an individual affected by jet lag can be measured with scales that incorporate the various aspects of jet lag including drowsiness, insomnia and impaired cognitive function, such as the Charité jet lag scale (Becker, Penzel & Fietze 2015b), the Columbia jet lag scale (Spitzer *et al.* 1999) and the Liverpool jet lag scale (Waterhouse *et al.* 2007). For business travellers, the effect of jet lag on cognitive function is of particular importance.

Team performance and the measurements used for it are now explored.

3.6.2 Team Performance

There are many ways to measure team performance, and this measurement can be summarised as having two approaches: metric-driven or survey-based. Using a quantitative, metric-driven approach, there are scales to measure team performance (Kendall & Salas 2004; Pritchard *et al.* 1988), although using these scales can be cumbersome and time-consuming (Mathieu *et al.* 2008). A purely metric approach to measuring team performance has also been used (Hauser 2001; Lynn & Reilly 2000). However, there is also literature that outlines measuring team performance using surveys with Likert scales (Ahammad *et al.* 2016; McDonough, Kahnb & Barczaka 2001; O'Leary & Mortensen 2010), as well as using questionnaires and focus groups to assess virtual team performance (Ferreira, de Lima & da Costa 2012; Lurey & Raisinghani 2001).

Because of the challenges with measuring team performance in the R&D environment (Hung 2017), this study uses questionnaires with a Likert scale to assess performance (Ahammad et al. 2016; Ferreira, de Lima & da Costa 2012; O'Leary & Mortensen 2010). Questionnaires have been used to measure performance in a study with Canadian biotechnology firms (Hall & Bagchi-Sen 2002), and the Australian biotechnology industry is the research context for this study.

This thesis now examines performance at the firm level.

3.6.3 Firm Performance

Measuring organisational performance is complex and has multiple dimensions (Richard *et al.* 2009), and there are two main approaches. Innovation performance can be measured using a metric approach such as return on investment (Mankin 2007) or other quantitative methods.

As with team performance, while quantitative methods can be useful for measuring firm performance, qualitative methods using surveys and questionnaires have also been reported. In a study comparing objective and subjective measures of performance in firms, Dess and Robinson (1984) found a significant correlation between these two sets of measures. In a comprehensive review of performance measurement, 23% of articles measuring performance in peer-reviewed management journals used surveys exclusively to assess performance

(Richard *et al.* 2009). Performance measurement now needs to take into account global networks rather than individual firms, adding another level of complexity (Bititci *et al.* 2012).

One method of evaluating firm performance that has gained popularity is the balanced scorecard approach, which incorporates translating a vision, communication, planning and feedback and learning, rather than relying on short term sales targets (Kaplan & Norton 1996). There are many ways of categorising this methodology rather than a single methodology (Perkins, Remmers & Grey 2014), and there are limitations to its use (Chytas, Glykas & Valiris 2011). There has been criticism of its use which has been characterised as being 'persuasive rather than convincing' (Nørreklit 2000; Nørreklit 2003). The use of the balanced scorecard in one study had a negative impact, resulting in a 'decrease in line managers' and employees' ability to cope with their workload' (Antonsen 2014).

Measurements taken of performance in the biotechnology arena include the number of biotechnology patents (Hagedoorn, Lokshin & Malo 2018; Niosi & McKelvey 2018), amount of venture capital investment and revenues (Gittelman 2006), all readily quantifiable measures and objectively visible rather than the more abstract measures used in the balanced scorecard approach.

While globalisation adds to the complexity of measuring performance, cross-border collaboration generally enhances a firm's performance (Kafouros *et al.* 2008; Sivakumar *et al.* 2011), and the globalisation of R & D supports innovation performance (Hsu, Lien & Chen 2015). In an analysis of this sector that examined firm performance, questionnaires were used to measure business performance in a survey of Canadian biotechnology firms (Hall & Bagchi-Sen 2002). Similarly, in this study surveying the Australian biotechnology sector, performance has been self-reported by the subjects.

These measures of performance are now summarised.

3.6.4 Summary of Performance

At the individual level, performance can be affected by jet lag, particularly cognitive performance such as focus (DeSanctis 2017; Goel *et al.* 2009; Killgore & Weber 2014), as well as the stress of business travel (Chen 2017; Ivancevich, Konopaske & Defrank 2003), particularly with regard to family life (Gustafson 2012b). For both team and firm level performance, globalisation offers challenges (McDonough, Kahnb & Barczaka 2001) as well as rewards (Espinosa, Nan & Carmel 2007; Sivakumar *et al.* 2011). This performance can be measured in a variety of ways, such as quantitative metrics (Kendall & Salas 2004) or the use of surveys (Ahammad *et al.* 2016; Richard *et al.* 2009). This literature review is now summarised below.

3.7 Summary

The biotechnology industry is heavily dependent on innovation (Hall & Bagchi-Sen 2002), and despite its geographical isolation, Australia rates highly in terms of biotechnology innovation (Gilding 2008).

For innovation to work, particularly for global projects, virtual teams are necessary (Bell & Kozlowski 2002). Virtual teams have disadvantages with long working days and communication issues due to the time zone differences within the team, as well as the lack of face-to-face contact, which can be offset by some members travelling (Siebdrat, Hoegl & Ernst 2009).

Organisational culture also has an impact on performance, influencing whether long hours are accepted, shaping attitudes towards maintaining a healthy work-life balance, and influencing the level of support available for workers who travel for business (Balthazard, Cooke & Potter 2006).

A significant factor that can affect performance is jet lag for team members that travel, which is common in many teams. Of particular interest is the effect of jet lag on cognitive function for the cohort of business travellers (Czeisler & Fryer 2006), however, little research has been conducted specifically looking at business travellers and cognitive function.

The measurement of performance at the individual, team and firm levels is complex (Richard *et al.* 2009), with globalisation adding a degree of complexity (Espinosa, Cummings & Pickering 2012), and the use of surveys to assess performance has been described in relevant management literature (Richard *et al.* 2009).

This thesis now describes the conceptual framework used.

4 Conceptual Framework

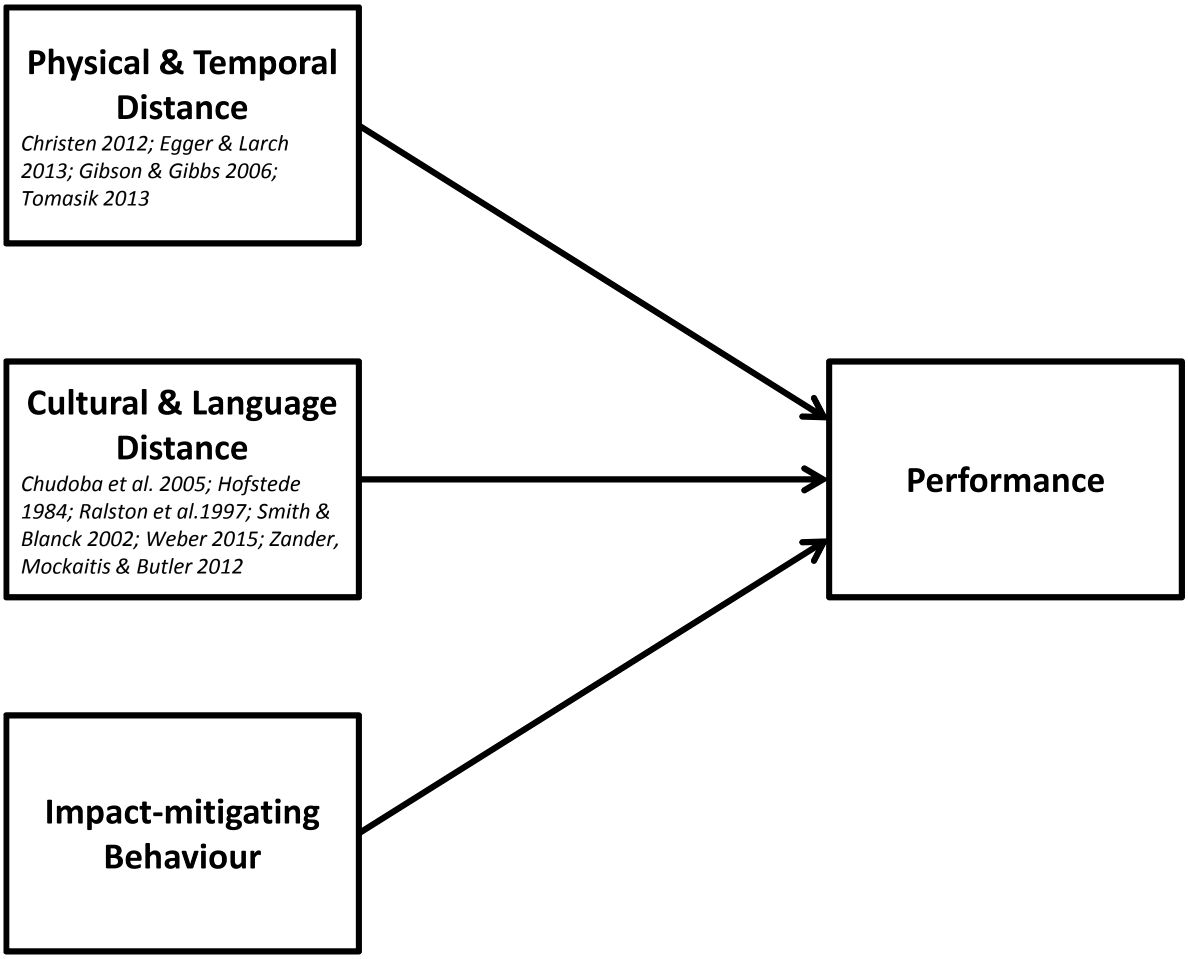
4.1 Introduction

In order to isolate the effects of temporal distance on team performance, it is necessary to extract it from other confounding factors, namely the other forms of distance: physical, cultural, and language, which have all been identified as barriers to the success of dispersed teams (Ferreira, de Lima & da Costa 2012). These four forms of distance (temporal, physical, cultural and language) are discussed in detail below.

4.2 Conceptual Model

Taking the themes identified in the academic literature, the following presents a model of team distance (Figure 4, below) that incorporates the factors that affect a dispersed team's performance due to the various types of distance within a team. There are four types of distances encountered in geographically dispersed teams: physical, temporal, cultural and language. The physical distance (as measured in kilometres) is closely linked but distinct from the temporal distance (as measured in the difference in time zones), as partners operating many time zones apart will be, by necessity, some distance apart unless they are in extreme polar regions (Christen 2017; Tomasik 2013). Similarly, culture is associated closely with language (Chen & Lin 2018; Weber 2015), so that these dimensions of distance have some correlation although are distinct. Lastly, there are impact-mitigating behaviours that can have a positive or possibly a negative effect on team performance, and the interaction between these factors is outlined in Figure 4 below.

Figure 4: Model of Team Distance



The negative effects of team dispersion can be ameliorated by various means, including using configuration, modern communication technology and having face-to-face meetings. It can be seen from the model that all four measures of distance, temporal, physical, cultural and language pose challenges to the team's performance. This model also considers the close link between temporal and physical distance described earlier, also the close link between cultural and language distance. The negative impacts of the various forms of distances can be ameliorated to some degree by various impact-mitigating behaviours, and this study will look at the behaviours used to address the temporal distances within global innovation teams.

These individual measures of distance as well as impact-mitigating behaviours are now examined individually.

4.3 Temporal and Physical Distance

4.3.1 Temporal Distance

This section addresses the effects of temporal distance within teams, including the segmentation of time into time zones, briefly outlining the history of time zones, the directionality of time, cultural perceptions of time, the concept of virtuality, economic models of time zone disparity, and finally, the effect of temporal distance on productivity.

The need to segment time into geographical time zones is caused by the rotation of the earth, with the current system established at the 1884 International Meridian Conference (Howse 1980, pp. 38-51, 94, 127-31). Time zones are usually plus or minus a whole number of hours from Universal Time, with a few places adding half hours to Universal Time (e.g., South Australia, India), and many regions add an extra hour during the summer months for daylight saving. With teams in separate time zones, this can lead to different levels of productivity when the working hours of team members in different time zones overlap *versus* when they do not overlap (Olson & Olson 2000).

Unlike the physical dimensions of space, time has directionality to it, an 'ahead' and a 'behind' component. This 'arrow of time' is quite unlike the spatial dimensions, in that it is irreversible (Hawking 1985; Lebowitz 1993; Paluš *et al.* 2018), with the difference between time zones having an 'ahead' and a 'behind' component. This directional nature of time has implications in areas such as logistics, where a deadline in Australia is approximately half a day ahead of Europe and almost a full day ahead of the United States.

Apart from the directionality of time, time is also different from the other forms of distance in that it is also subject to a high degree of cultural interpretation (Block, Buggie & Matsui 1996; Mosakowski & Earley 2000), and can be manipulated by external means (Thönes, Arnau

& Wascher 2018). The perception of time alters with culture, with Levine & Bartlett (1984) finding that several time-observant behaviours (clock accuracy, walking speed and efficiency of postal delivery) varied substantially between nations in a large-scale international survey conducted in 53 nations (Wang, Rieger & Hens 2016). Similarly, in measuring the perceived direction of time, in a study of 125 people (50 Spanish, 75 Moroccan), de la Fuente *et al.* (2014) noted that Spanish test subjects typically perceived the future ahead of them and the past behind them (as usually perceived in English), while Moroccan subjects typically perceived the reverse. While time is a key measurement in physics, it is also part of a broader cultural narrative. The standard measurement of time perspective in cultural terms is the Zimbardo Time Perspective Inventory (Sircova *et al.* 2014; Zimbardo & Boyd 1999, 2015). This cultural time perspective may have an influence on intelligence (Zajenkowski *et al.* 2016) and has also been shown to display an underlying neuroanatomical basis (Chen, Guo & Feng 2017), and has an impact on individual and societal function.

4.3.2 Temporal Distance and Economics

There have been several economic modelling studies examining the effect of time zone differences on global trade. Time zones have been described as a cost of doing business (Bista & Tomasik 2017), and time zone disparity and the resulting logistical issues are a barrier for trade (Ferreira, de Lima & da Costa 2012; Nordas, Pinali & Grosso 2006), although this negative effect of time zone disparity can be offset by communication mechanisms (Espinosa, Nan & Carmel 2015). The effect of time zone disparity on the trade of goods is different to its effect on the trade of services, which is again different to access to venture capital. It would be expected that disparate time zones would have a negative impact (the 'synchronisation effect') on the trade of goods, and this finding has been borne out (Egger & Larch 2013; Stein

& Daude 2007; Tomasik 2013). These time zone effects are greater as the time zone difference is increased (Bista & Tomasik 2017).

In the case of trade in services (as opposed to trade in goods), the effect of time zone disparity is positive. Marjit (2007) has suggested that countries in differing time zones can actually save time and production costs if transportation costs are minimal (for example, electronically), and a rolling 24-hour production line can be created. For example, an information technology company with offices in the United States and India, may have work flowing in a continuous 24/7 pattern from one office to the other. The benefit conferred by this time zone disparity is referred to as the 'continuity effect' (Head, Mayer & Ries 2009), and the workflow pattern is referred to as 'follow the sun' (Carmel, Espinosa & Dubinsky 2010). There has been shown a positive, rather than negative, benefit for services trade with time zone disparity (Kikuchi & Iwasa 2010), with time zone disparity as a driver of growth in global service industries (Kikuchi & Marjit 2011). However, offshoring service industries to regions with different time zones alters the industrial structure dramatically (Kikuchi & Long 2010; Matsuoka & Fukushima 2010). This 'follow the sun' workflow pattern can be beneficial in terms of labour costs, provided that the transport costs are minimal (Kikuchi, Marjit & Mandal 2013; Nakanishi & Long 2015). Head *et al.* (2009) found that the longitudinal (east-west, sensitive to time zone differences) distance had a much greater impact than latitudinal (north-south, no sensitivity to time zone differences) distance in terms of service trade, and affiliate sales are increased in countries with disparate time zones (Christen 2017). Similarly, for virtual trade, increasing the difference in time zones between two sites can increase the rate of growth of the company (Marjit & Mandal 2017).

The pattern for venture capital is similar to that of trade of goods, in that venture capital is more commonly available for small companies from local venture capital providers, and investment patterns demonstrate a strong regional bias (Powell *et al.* 2002). Time zone difference, like physical distance, is therefore a negative factor for securing venture capital.

The biotechnology industry, while ultimately trading in goods, relies greatly on services, with its heavy reliance on knowledge and intellectual property (Owen-Smith & Powell 2004; Zucker, Darby & Armstrong 2002), and is very much dependent on access to venture capital (Gilding 2008). The biotechnology industry represents a sector that appears to be neither a pure trade in goods nor a pure trade in services, but something intermediate, opening the possibility for an expansion of the current model of the effects of time zone disparity into this area. It appears that temporal distance has both negative and positive effects on trade in the biotechnology industry, and this study will determine whether the net effect of time zone differences is a positive or a negative one.

4.3.3 Temporal Distance and Productivity

Time zone differences also have a generally negative effect on productivity. Communication patterns are affected greatly by temporal distance (Bøler, Javorcik & Ulltveit-Moe 2018; Espinosa, Nan & Carmel 2015), and the pace of work is different in sites in different time zones when the workday overlaps *versus* when it doesn't (Olson & Olson 2000). In the biotechnology sector, a study of 7,162 scientific teams showed that innovative novelty had an inverted U-shape against temporal distance, increasing and then decreasing as the temporal distance increases (Tzabbar & Vestal 2015), so that a small time zone distance had a positive effect on innovation, while a large time zone difference had a negative effect on innovation. However, as previously discussed, team productivity can also be enhanced by time zone separation, allowing a 'follow the sun' model of work (Carmel, Espinosa & Dubinsky 2010), allowing for 24/7 operations (Manning, Larsen & Bharati 2015).

4.3.4 Physical Distance

Physical distances within a team are a challenge to the team's performance (Eisenberg, Post & DiTomaso 2019), and in organisations that use virtual teams that are separated by distances, both the distance and the virtuality are two major problems in terms of work processes and productivity (Chen *et al.* 2016), with physical distance creating additional challenges in the management of virtual teams (Siebdrat, Hoegl & Ernst 2009). Importantly, the effect of physical distance is distinct to that of temporal distance (Christen 2017; Tomasik 2013), although sites that are physically distant are typically temporally distant and *vice versa*.

However, physical proximity has also been noted as a positive factor in scientific collaborations (Kabo *et al.* 2014), supporting the development of innovation (Abramovsky & Simpson 2011). If two places are a long way apart temporally, they must by necessity be physically quite separated, except for the Polar Regions. However, physical distance is a barrier economically for groups, and in terms of international trade 'the negative effect of distance on trade is one of the clearest and most robust empirical findings in economics' (Leamer & Levinsohn 1994), with a strong inverse relationship between distance and trade (Tomasik 2013). Conversely, geographical proximity between industry and universities strengthens the collaborative links (Vedovello 1997), encouraging the formation of clusters, which Porter (1998) defines as 'geographic concentrations of interconnected companies and institutions in a particular field'.

Culture has some role in overcoming physical distance, and the concept of 'psychic' distance, a combination of cultural and language distance, can offset high physical distances (Chen &

Lin 2018). As a result, the objective distance in kilometres does not always translate into subjective distance within a virtual team (Siebdrat, Hoegl & Ernst 2013), but is one of several forms of distance.

Porter (1998), in his analysis of clusters identifies Boston and San Francisco as biotechnology clusters. These biotechnology clusters have also been identified by analysing the origin of publications, similarly identifying Boston and San Francisco as significant centres of activity in the biotechnology industry (Catini *et al.* 2015). In Australia, Melbourne has been identified as the major biotechnology hub for the Asia-Pacific region (Gilding 2008), with significant activity particularly in the Parkville precinct (Melbourne Biomedical Precinct 2017; State Government of Victoria 2017).

Overcoming the negative effects of physical distance on collaboration is one of the drivers for cluster formation (Engel 2015). There are several substantial advantages for the formation of clusters, particularly in the biotechnology industry. In terms of patents, a quantifiable measure of success, projects with local ties are more likely to be patented than projects with distant ties due to the benefit of proximity on productivity and innovation (Gittelman 2007). For biotechnology companies, proximity to knowledge sources is also useful for technology transfer, and the benefit of this proximity results in the formation of clusters (Davenport 2005). Access to venture capital is also vital for biotechnology companies as they scale upwards, and this leads to the formation of clusters of venture capital companies willing to invest in biotechnology enterprises (Kolympiris, Kalaitzandonakes & Miller 2011; Powell *et al.* 2002), and the formation of biotechnology clusters may attract government subsidies (Broekel, Fornahl & Morrison 2015). Australia, by way of contrast, is relatively isolated from other biotechnology hubs (Gilding 2008), and although Melbourne has been identified as a significant biotechnology cluster (Blanco 2012; Gilding 2008), and is arguably an emerging knowledge city (Yigitcanlar, O'Connor & Westerman 2008), it is a long way from other biotechnology clusters. This isolation has been described as the 'tyranny of distance' (Gilding 2008). However, there have been some significant localised collaborations within Australia to develop innovative products in biotechnology (Thompson *et al.* 2011).

Innovation is dependent on globalisation (Dodgson 2018; Kafouros *et al.* 2008) as previously discussed in detail in section 3.2.5. As innovation is globalised, there is increased collaboration with overseas partners (Archibugi & Iammarino 1999), and Australian biotechnology companies typically partner with American organisations (Gilding 2008; Guan, J & Chen, Z 2012). Because of the physical distance between collaborating institutions, virtual teams are created (as described in section 3.3). This physical distance is a key factor in terms of measuring virtuality (Gibson & Gibbs 2006; Gilson *et al.* 2015; Hoch & Kozlowski 2014), including Chudoba's model of virtuality (Chudoba *et al.* 2005).

Physical distance, like temporal distance, poses challenges to virtual teams in terms of productivity, innovation and management, and is a factor of virtuality in describing virtual teams. The similarities and differences between the effects of temporal and physical distances are now discussed.

4.3.5 Confluence of Physical and Temporal Distance

Physical and temporal distances are separate and distinct (Christen 2017), although there is a great deal of overlap between the two forms of distance (Tomasik 2013). Physical distance is typically measured in kilometres (or miles), and between any two places the physical distance can be calculated using the 'great circle distance' between the two places. It should be noted that although time zones differences and the physical distance between two locations are both based on location (and therefore have a very strong degree of correlation), these two dimensions are not identical. While physical and temporal distances are linked, these variables have some degree of independence. For example, Tomasik (2013) cites the example of the distances from Ottawa (Canada) to Sofia (Bulgaria) and Ottawa to Brasilia (Brazil) being similar, but the time zone differences very dissimilar. Similarly, Christen (2017) separated north-south distances from east-west distances in her analysis of delivery of services by foreign affiliates. While time zone disparity and physical distance are closely linked in terms of measures of distance, physical distance and temporal distance are nonetheless listed as separate dimensions in a model of global virtual teams by Jimenez *et al.* (2017).

Both physical distance, as measured in kilometres, and temporal distance, as measured by hours of time zone difference, can have negative effects on team performance. However, it is worth noting that ‘time separation, in the form of maximum time zone difference spanned by members, has a stronger negative impact on team performance than spatial separation’ (Espinosa, Cummings & Pickering 2012). While physical distance has a negative impact on performance, the negative impact of time zone disparity on performance is even greater.

Other measures of distance within global innovation teams, cultural and language, are now reviewed.

4.4 Cultural and Language Distance

4.4.1 Cultural distance

The need to manage the cultural distance within global teams, as well as physical and temporal distance, makes global teams more difficult to manage (Duarte & Snyder 2001, p. 67; Presbitero & Toledano 2018). Often there are restrictions on communication and limited face-to-face contact (Hertel & Orlikowski 2015), although collocated teams can still have difficulty with cultural barriers (Lipnack & Stamps 2000, pp. 66-7). As a result, cross-cultural awareness has been cited as one of the most important global multicultural team leader competencies for managing global teams (Gibson & Cohen 2003, pp. 109-10; Zander, Mockaitis & Butler 2012). These cultural differences have been quantified to some extent with the development of measurements of cultural dimensions by Geert Hofstede (Hofstede 1984), and Ralston *et al.* (1997) identifies additional insights to the effect of culture on management. This quantification of cultural differences has not been without its critics (Ailon 2008; McSweeney 2002a, 2002b, 2013), and although these cultural measures are significant at an aggregated national level, they are not applicable at the individual level (Brewer & Venaik 2012, 2014; Venaik & Brewer 2013). Moreover, the effect of cultural divergence is not necessarily significant for geographically dispersed teams. For example, in evaluating international transfers of biopharmaceutical technology from universities to businesses, using a formula for calculating the cultural distance between two nations using Hofstede's (1984) cultural dimensions, Malik (2013) found no adverse effect from cultural differences on team performance. Quantifying the cultural distance between two places is not as straightforward as physical distance, but it is certainly possible using the formula from Malik (2013) for calculating cultural distances from the cultural measures postulated by Hofstede (1984).

Cultural differences have been described as a barrier to the success of virtual teams (Ferreira, de Lima & da Costa 2012), with training in cross-cultural communication being potentially beneficial for team performance (Schmidtke & Cummings 2017). For global virtual teams that have a diversity of cultures, establishing communication patterns that are appropriate to the team's task is important (Maznevski & Chudoba 2000), further affirming the importance of strong communication channels in global innovation teams that incorporate a diversity of cultures.

In the particular context of the Australian biotechnology industry, 'the tyranny of distance has a cultural dimension', and partnerships with culturally distant nations in Asia are less likely than more culturally similar but physically and temporally distant nations such as the United States or the United Kingdom (Gilding 2008). The negative effects of cultural differences on global team performance are not limited to national cultures, but it can also be a hindrance at an organisational level, with organisational cultural differences between collaborating institutions potentially having a negative impact on performance (Ahammad *et al.* 2016).

It has been shown that for successful global innovation between diverse cultures, cultural intelligence is important (Henderson, Stackman & Lindekilde 2018), with communication across different cultures being particularly critical (Maznevski & Chudoba 2000). However, due to these cultural barriers, there is a reluctance to form business partnerships between divergent cultures, noted in the context of the study, the Australian biotechnology industry (Gilding 2008).

Having reviewed cultural differences as a barrier to global innovation team performance, language as a barrier to global collaboration in innovation is now discussed.

4.4.2 Language Distance

Language distance is used as a measure of virtuality in the model of virtuality proposed by Chudoba *et al.* (2005), who states that collaborating 'with people who speak different native languages or dialects from your own as a measure of virtuality'. Language barriers have been recognised as a challenge to the success of global teams (Eisenberg, Glikson & Lisak 2018; Ferreira, de Lima & da Costa 2012). In a study of 61 members of 14 global virtual teams with mostly Danish and Indian team members (with some members from Germany and Sweden), Klitmøller and Lauring (2013) proposed that 'low language commonality [is] negatively associated with communication effectiveness', and concluded that language use needed to be taken into consideration in geographically dispersed teams, and differences in language can have an adverse effect on global team performance (Gilson *et al.* 2015). Language and culture are firmly linked (Weber 2015), and therefore it is reasonable to expect that cultural distance and language distance are similarly linked, although these two dimensions have some degree of independence from each other.

Language distance between English and other languages has been quantified using Levenshtein distances (Petroni & Serva 2010; Wichmann *et al.* 2010). In terms of Levenshtein distances, some languages are closer to English (such as Norwegian or Swedish), and other languages are more distant from English (such as native speakers of Japanese or Mandarin Chinese). It is much easier to learn English for native speakers that have their native language closer to English in terms of Levenshtein distances (Chiswick & Miller 2005; Isphording & Otten 2014). The evolution of different languages has been likened to the biological evolution of different organisms (Serva & Petroni 2008). This language distance has a negative impact on communication in cross-cultural teams with a variety of languages, particularly within multinational organisations (Harzing & Feely 2008); strategies are needed within multinational organisations or global teams to bridge this language barrier (Grzeszczyk 2015). As a direct result of the language barrier between nations, there is an economic cost, with language distance having a strong negative influence on bilateral trade volumes (Isphording & Otten 2013). By way of contrast, language similarity has a strong positive impact on international collaboration (Manning, Larsen & Bharati 2015).

Language has been cited as a key factor as to why Australian biotechnology companies typically partner with American and British organisations rather than Asian ones (Gilding

2008). These companies favour collaborations with nations that are a long way in terms of physical and temporal distance but have more language similarity, rather than a more physically and temporally proximate but linguistically distant Asian partner, even though Australia's key trading partners are in Asia (Department of Foreign Affairs and Trade 2012, 2014).

Having examined the barrier that language distance places within global innovation teams, this review now examines the confluence between the two similar, but distinct measures of distance previously discussed, cultural and language distances.

4.4.3 Confluence of cultural and language distance

Language and culture have both been identified as barriers to the success of dispersed teams (Ferreira, de Lima & da Costa 2012), and language is heavily influenced by culture (Weber 2015). The combination of cultural and language distance within teams has been described as 'psychic distance' (Chen & Lin 2018), preventing the flow of information within the company (Dinner, Kushwaha & Steenkamp 2018).

In the Australian biotechnology industry, 'cultural propinquity', which includes language as well as cultural factors, facilitates collaboration with Australian companies, so that partnerships are more commonly formed with the United States and United Kingdom rather than the physically and temporally closer, but more culturally distant, Asian nations (Gilding 2008). However, while it has been noted that while cultural and language barriers are significant issues in globally dispersed teams, there may also be deeper employee concerns and struggles in these teams (Lockwood 2015).

Temporal, physical, cultural and language distance all generally have a negative impact on performance for global innovation teams. This review now turns to the strategies that teams use to ameliorate these negative impacts on performance.

4.5 Impact-Mitigating Behaviour

In order to offset the 'tyranny of distance' (Gilding 2008), teams use a number of strategies to overcome the negative effects of the various types of distance on performance. Some of these strategies are outlined below.

4.5.1 Team Composition

One way to offset the negative effects of the various forms of distance on global innovation team performance is to modify the composition of the team. In a study of 62 six-person geographically dispersed teams by O'Leary & Mortensen (2010), the authors found that geographical configuration has a significant effect on dispersed teams; specifically, teams with members who had no teammates at their sites performed better (in terms of identification, transactive memory, conflict, and coordination) than teams with multiple members at a single site, and concluded that 'the existence of geographic isolates (team members who work alone at a site) have significant effects on team dynamics'. These findings were mirrored by Polzer *et al.* (2006), who found that having subgroups created 'geographic faultlines' which 'heightened conflict and reduced trust' within the teams, and suggest that 'managers should avoid creating teams with strong faultlines by paying attention to the combination of demographic and geographic characteristics of potential members' of a virtual team.

Geographical configuration is not the only factor to account for in team composition, but the composition of personalities within the virtual team has also been explored (Hoch &

Dulebohn 2017), and 'the relationships between team personality composition and virtual team performance are indirect'. The composition of the global innovation team, both geographically and in terms of personality, can potentially mitigate and exacerbate some of the negative effects of the four types of distance on team performance.

4.5.2 Communication Technology Strategies

The use of communication technology such as internet-based conferencing applications, real-time online discussions (such as chat or instant messaging), videoconferencing and the use of mobile devices were all listed as measures of virtuality in globally dispersed teams by Chudoba *et al.* (2005). Video conferencing is often used as a substitute for long-distance international travel (Lu & Peeta 2009). However, this use of modern communication technology may not necessarily translate to enhanced performance. In a survey of 67 individuals in 12 different virtual teams, Lurey and Raisinghani (2001) evaluated their effectiveness and found that communication technology did not prove to be significant predictor of team performance. These findings were mirrored by Lin, Standing and Liu (2008) who found that social dimension factors (relationship building, cohesion) were more significant for building effective virtual teams than modern communication technology. While communication technology has improved substantially and become much more affordable in recent decades, this improvement in communication technology may not have necessarily resulted in significant improvement in the performance of globally dispersed teams. Communication strategies have been discussed in section 3.3.6.

4.5.3 Face-to-Face Contact

Although video conferencing has been used substitute for long-distance international travel (Lu & Peeta 2009), face-to-face meetings are important for globally dispersed teams

(Siebdrat, Hoegl & Ernst 2009; Welch, Welch & Worm 2007). This face-to-face contact has been likened to a 'rhythm of communication' or a 'heartbeat' (Kelley 2001; Maznevski & Chudoba 2000) strengthening relationships within the team (Gibson & Cohen 2003, p. 18). However, the use of face-to-face meetings comes at a cost, not only in terms of airfares and accommodation, but also performance, as business travellers are exposed to jet lag (Cohen & Gössling 2015). The importance of face-to-face meetings has been discussed in detail previously in sections 3.3.4, 3.3.6 and 3.4.3.

4.5.4 Management Strategies

As previously noted in section 3.3.4, the skill set for managing virtual teams is completely different to that of managing collocated teams, requiring inspirational leadership and trust (Joshi, Lazarova & Liao 2009). Virtual teams tend towards shared team leadership, rather than a more traditional hierarchical structure, and this shared team leadership has been linked to improved team performance in a sample of 101 virtual teams (Hoch & Kozlowski 2014). The style of leadership within globally dispersed teams is also important, with a charismatic and transformational leadership style showing a stronger positive impact (Wang, Waldman & Zhang 2014), as does an inspirational leadership style (Joshi, Lazarova & Liao 2009). Trust is particularly crucial for virtual teams, more so than for collocated ones (Muethel, Siebdrat & Hoegl 2012), especially with the challenges of working across multiple time zones (Kanthak & Hertel 2016). Trust within a virtual team positively affects collaboration, but not necessarily a global team's performance (Alsharo, Gregg & Ramirez 2017).

Communication is also particularly important in globally dispersed teams (Ferreira, de Lima & da Costa 2012; Jarvenpaa & Leidner 1999), and strong communication within virtual teams results in reduced levels of conflict (Hinds & Mortensen 2005) and enhanced performance

(Gibson & Gibbs 2006). This communication has been greatly enhanced with innovations allowing team members to communicate frequently (Gilson *et al.* 2015; Song & Song 2010).

Because global innovation teams are typically cross-cultural, having cultural awareness is an important management skill (Zander, Mockaitis & Butler 2012), and cross-cultural training and cultural sensitivity have been identified as being critical for team effectiveness (Scott & Wildman 2015).

Even though often there are team members in dispersed teams that frequently travel, there is a dearth of literature that describes the management of these employees. As outlined in section 3.4.3, there are considerable challenges for team members who travel, the physical stresses which are compounded by psychological stresses (Mäkelä & Kinnunen 2018), not only for the employee (Striker *et al.* 1999) but also their families (Dimberg *et al.* 2002; Espino *et al.* 2002; Welch & Worm 2006, pp. 287-8).

While dispersed teams are more difficult to lead, and communication adds significant challenges to the management of globally dispersed innovation teams, the configuration, leadership styles, and relationships within the teams are more significant than the communication technology used by the teams.

The four forms of distance in globally dispersed innovation teams, the behaviours that ameliorate the impact of these forms of distances and performance have all been incorporated into the conceptual model.

4.6 Summary

This review has examined the literature regarding globally dispersed innovation teams and the effect of temporal distance on performance. There is an opportunity for research in assessing the effect of time zones differences on dispersed team performance using the

Australian biotechnology sector as a case study, to examine the research question *'What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?'* With the Australian biotechnology industry's temporal isolation from other biotechnology hubs, its relative proximity to Asian nations, and the innovative nature of biotechnology, the Australian biotechnology industry makes an excellent setting for assessing the effect of time zones on dispersed team performance and will contribute to theory in temporal disparity and its effects on the performance of geographically dispersed global innovation teams.

5. Methodology and Research Design

5.1 Introduction

This chapter discusses the methodology and research design of this study, which is mixed method. The underlying ontology and epistemology of the study is firstly addressed. Then this chapter discusses the qualitative phase of the study: the methodology; methods of data collection, including the sampling and demographics; and the analysis of the qualitative data to elucidate the themes to be measured in the second phase of the study. The quantitative phase of the study is then discussed: the survey methodology; how the survey participants were selected; how the data was collected; the questionnaire used in the survey; the variables that were extracted from the survey; and finally, an overview of the variables. The methodology and research design of this study are then summarised.

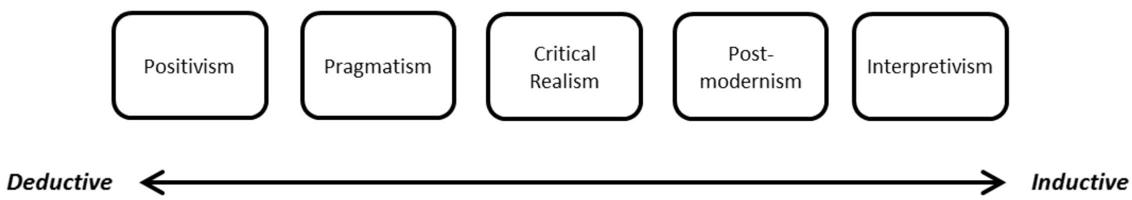
5.2 Ontology & Epistemology

5.2.1 Ontology

There are several ontological paradigms which range on a spectrum from positivism and interpretivism, with the paradigm of critical realism as an intermediate (Mingers 2004). The spectrum of ontological paradigms with some key paradigms is outlined in the figure below.

Figure 5: Ontological Paradigms

(Saunders, Lewis & Thornhill 2009, pp. 136-7)

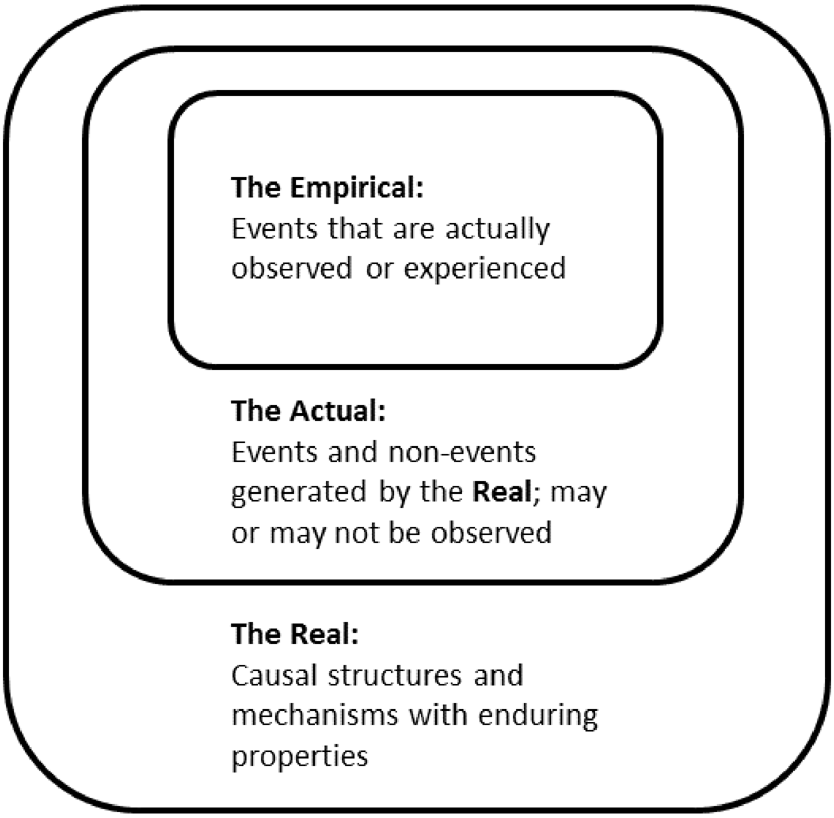


The ontological paradigm used in this study is critical realism, in which the factors that influence behaviour are not immediately apparent but need to be identified. As Bhaskar says (2010, p. 2), ‘we will only be able to understand – and so change – the social world if we identify the structures at work that generate those events and discourses… these structures are not spontaneously apparent in the observable pattern of events; they can only be identified through the practical and theoretical work of the social sciences’. In the critical realism paradigm, reality is known by its patterned characteristics, and can be modelled and its behaviour anticipated, even though participants’ accounts differ (Hallebone & Priest 2009, p. 172). Critical realism uses causal language to describe the world (Easton 2010), and conceptualising reality is simply a way of knowing reality (Bryman & Bell 2011, p. 17). This study identifies these factors both through the academic literature, and then in the qualitative phase of the study to generate factors that were measured in the quantitative phase of the study.

Critical realism distinguishes between three distinct domains: the empirical, which are the aspects of reality that can be experienced directly; the actual, which may or may not be experienced; and the real, which are the deep causal structures that underlie and generate events (Bhaskar 2008, p. 2). An illustration of the three domains and their interaction taken from Saunders, Lewis and Thornhill (2009, p. 139) is given in the figure below.

Figure 6: Three Domains

(Saunders, Lewis & Thornhill 2009, p. 139)



The reason for selecting the ontology of critical realism is that this study is not seeking immutable laws (positivism), nor only the lived experience of social actors (interpretivism), but rather deeper levels of understanding (McEvoy & Richards 2006). Positivism focuses only on observable events, not accounting for theoretical frameworks (Olsen 2004), and does not deal with the interactions of social systems (Collier 1994), while interpretivism fails to examine underlying social structures which may have an impact on social actors (Granovetter 1985; Williams 2003). The effect of time zone differences in global innovation team performance may not be immediately obvious and may be context-specific (Gilson et al. 2015; O'Leary & Mortensen 2010). Critical realism allows for structures that are not immediately apparent: 'social products… are used to explore the unknown (but knowable) intransitive structure of the world' (Bhaskar 2008, p. 13). This makes critical realism a suitable ontological paradigm for studying issues in social sciences, having neither the rigidity of the focus on observable events of positivism nor overlooking the underlying social structures as does interpretivism.

Having explored the ontology of this study, this thesis now turns to the epistemology of this study.

5.2.2 Epistemology

The epistemological approach taken in this study is inductive, in line with the critical realist approach of the study: 'substantialism, which takes reality as material, but acknowledges that people interpret it differently in different times and contexts. A case study approach has been taken for this study (Eisenhardt 1989), inducting theory in an approach that is highly iterative, these iterations being dependent on the data extracted. This epistemological view is most often associated with the position called critical realism' (Eriksson & Kovalainen 2008, p. 15). An important basic tenet of critical realism is that ontology, the nature of reality, is 'not reducible to epistemology', that is, our knowledge of reality (Fletcher 2017), but instead there is an 'epistemological fallibilism', which acknowledges that theories are fallible, although some theories describe reality better than others, with the three pillars of critical realism described as 'ontological realism, epistemological fallibilism and judgmental rationality' (Yucel 2018). Using a critical realist perspective allows elements of induction and deduction in its epistemology, allowing for both retroduction (working out what might have caused the observations) and abduction (grasping the inner meaning of a phenomenon) (Olsen 2004). The epistemology of this study is therefore inductive and subjective, permitting fallibility in theory because it is only the empirical (or observable) events that can be measured, and not the underlying ‘real’ realm responsible for the causal structures (Saunders, Lewis & Thornhill 2009, p. 139).

This inductive epistemology used in critical realism lends itself to mixed methods, which permits triangulation of data (Jick 1979; Olsen 2004), synergising the benefits of both qualitative and quantitative methodologies (Hussein 2009). The mixed method approach used in this study is now discussed in detail.

5.3 Mixed Method Approach

The mixed method approach used in this study combines qualitative and quantitative data to provide better triangulation of the data. The use of mixed methods approach allows one to determine whether the two data sets have converged (Jick 1979) and allows exploratory findings to be generalised (Creswell & Plano Clark 2011, pp. 9-10). The combination of qualitative and quantitative approaches has the benefit of synergy between the two methodologies: ‘when combined there is a great possibility of neutralizing the flaws of one method and strengthening the benefits of the other for the better research results’ (Hussein 2009). The approach taken in this study is an exploratory mixed method approach, using qualitative data to explore the themes from the subject population, and these themes are then addressed in the qualitative phase and synthesised, examining the extent and in what ways the quantitative results test the qualitative results (Creswell & Plano Clark 2011, pp. 88-9). The two study methodologies are therefore complementary in this study and combine ‘the power of stories and the power of numbers’ (Pluye & Hong 2014). The methodology of the qualitative phase of this study is now discussed.

5.4 Qualitative Phase Methodology

In line with critical realism, the methodological approach for this study is mixed method: an initial qualitative series of interviews to determine the concepts and factors that influence the effects of time zone disparity on the performance of dispersed innovation teams in the Australian biotechnology sector, followed by a quantitative survey to 'synthesise, test and validate an effective cause-effect model of phenomena' (Hallebone & Priest 2009, p. 66). In this study, qualitative research will be used to facilitate quantitative research, with the quantitative survey (using Likert scales) constructed after being informed by qualitative data from interviews (Bryman & Bell 2011, p. 634; Carpenter *et al.* 2016).

The first phase of the study is qualitative, based on one-on-one interviews with individuals in time zone disparate teams with dispersed innovation projects. Interview subjects were typically recruited at biotechnology meetings (particularly the AusBiotech conferences in 2015 at the Gold Coast, and 2016 in Melbourne). A key informant approach was used, with one member from a team interviewed (Algesheimer, Bagozzi & Dholakia 2015). There was a discussion prior to each interview and informed consent was obtained from all informants prior to the interview. The signed consent forms are kept securely in a locked cupboard at RMIT, with the informed consent forms stored separately from the table listing participants and their interview dates and details. The qualitative phase of the research consists of 28 interviews, with over eight hours of interview data.

The methodology for this study uses a case study approach, using *a priori* constructs derived from the literature and multiple collection methods, namely a series of interviews followed by an online survey (Eisenhardt 1989). This reliance on theoretical concepts is an important strategy in case studies (Yin 2003a, p. 3), and useful in conducting descriptive case studies.

The case study approach allows the construction of a theoretical construct, bridging the qualitative evidence from the interviews, and using them to create testable theoretical propositions inductively (Eisenhardt & Graebner 2007). There are multiple units of analysis within the case study design (Yin 2003b, p. 40), as multiple variables are examined (refer to sections 5.8 and 5.9), although there are the limitations of using self-reported data (Chan 2009).

Data saturation was an important consideration in this study, particularly in the qualitative phase. In a qualitative study with 60 interviews, saturation was deemed when data codes were no longer created. With this data set, saturation occurred within the first 12 interviews, although most of the codes were created in the first six interviews (Guest, Bunce & Johnson 2006). However, in a study with 25 in-depth interviews, while code saturation was reached after nine interviews, the 'meaning saturation', where there was 'a richly textured understanding of issues', did not emerge until 16 to 24 interviews (Hennink, Kaiser & Marconi 2016). There was a total of 28 interviews in this study, and by the conclusion of the interviews it was understood that not only was there code saturation, but also meaning saturation, and there was no further advantage in continuing with any more interviews.

5.5 Qualitative Phase Data Collection

Interviews took place in quiet areas without distractions (such as telephones, computer terminals or excessive ambient noise), using a Zoom H2 sound recorder accessed from RMIT Audio-visual Loans Department. These interviews were transcribed within a few working days to a written record, which was also forwarded to the interviewee. Open questions were used to elicit understandings and explore the interviewees' perspectives (Quinlan 2011, p. 293). Interviews of approximately 30 to 60 minutes in duration were adequate for this initial exploratory phase (Hackley 2003, p. 119), with the number of interview subjects was twenty-eight (28) informants. The intention of the qualitative analysis was not to obtain saturation, but rather to generate themes for further research in the quantitative survey (Corbin & Strauss 2008, pp. 156-7). Any reference to material that was commercial-in-confidence such as company names, personnel names or data was specifically asked to be avoided, and any accidental reference to potentially sensitive material was redacted from the interview transcript.

NVivo was used as the tool to elucidate the significant themes in the topic, to identify factors that affect the performance of dispersed teams. It should be noted that coding was performed manually, and the automatic coding function of the *NVivo* software was not used. Informants were recruited through networking events in the Australian biotechnology sector.

Nineteen of the interviews were conducted by telephone, rather than face-to-face. The validity of telephone interviews providing similar results to face-to-face ones was demonstrated in a series of interviews of 43 people, 21 of which involved face-to-face interviews, and 22 were conducted by telephone, and the authors concluded that telephone interviews are effective in qualitative research (Sturges & Hanrahan 2004), and this finding that telephone interviews are as effective as face-to-face interviews has been duplicated in a large number of studies (Drabble *et al.* 2015; Mahfoud *et al.* 2014; Vogl 2013). In addition, similar responses were obtained across face-to-face and telephone approaches, although it has been noted that telephone interviews are often shorter than face-to-face ones (Irvine 2011; Irvine, Drew & Sainsbury 2012), which is also the case with the qualitative data that underlies this study. Apart from face-to-face interviews, telephone interviews are a valid means of interviewing subjects, especially in the context of an industry that is distributed widely across Australia with almost half of the interview subjects not being based in Melbourne (refer to Figure 6).

5.5.1 Sampling

The total sample consists of 28 interview subjects working in time zone disparate teams in the Australian biotechnology context, from a range of organisations at relevant industry events (see Table 2). The inclusion criteria for subjects participating in the survey are:

1. Currently working in the Australian biotechnology industry (*e.g.*, pharmaceuticals, medical devices, agriculture);
2. Be working or have recently been working with innovative (R&D) products; and
3. Be or have been part of or in charge of an internationally geographically dispersed team working with these innovative products.

Exclusion and inclusion criteria were applied at the beginning of interviews to ensure that informants meet the criteria above. As all participants are competent adults and participation is entirely voluntary (with no power imbalances such as employer / employee), no ethical issues are anticipated. Study participants were recruited through industry events (most commonly AusBiotech events, as well as biotechnology innovation groups in Meetup. Informed consent forms were signed by all participants (see Appendix A). Data was analysed using comparative case description for the qualitative interviews (seven in total). See Discussion section below.

In total, 28 people were interviewed in the twelve months from March 2015 to March 2016. All were currently working in the Australian biotechnology sector as part of innovation teams that spanned across multiple time zones. Interviews were numbered 01 to 28, with leading zeros used for clarity and consistency. When an interview is quoted the format is (interview number minute:second), so that the reference (13 12:23) refers to material from interview 13, commencing at the 12 minute and 23 second mark. In one instance (interview 04), the sound recording failed and the results have been taken from notes taken during the interview. Table 2 shows the interview data, with more than eight hours in total of interviews data in a total of 28 interviews, and an average interview length (excluding the interview where the sound equipment failed) of approximately 20 minutes. As the interviews progressed, data saturation was approached, and there was a slight but noticeable trend of the interviews decreasing in length as there were fewer new themes being elucidated from the interview subjects. The interview data are listed below in Table 2.

Table 2: Interview data

Interview #	Date of interview	Mode of interview	Duration (min:sec)
01	25/03/2015	Face-to-face	17:53
02	31/03/2015	Face-to-face	24:48
03	23/04/2015	Face-to-face	14:03
04	28/04/2015	Telephone	(sound equipment failure)
05	28/04/2015	Telephone	10:55
06	28/04/2015	Telephone	14:06
07	28/04/2015	Face-to-face	22:17
08	28/04/2015	Telephone	18:58
09	04/11/2015	Telephone	20:27
10	05/11/2015	Telephone	23:36
11	13/11/2015	Telephone	28:12
12	13/11/2015	Telephone	18:07
13	13/11/2015	Telephone	27:59
14	27/11/2015	Telephone	19:26
15	27/11/2015	Telephone	22:32
16	30/11/2015	Telephone	11:31
17	14/01/2016	Telephone	19:02
18	14/01/2016	Telephone	25:04
19	21/01/2016	Telephone	18:06
20	21/01/2016	Face-to-face	14:54
21	21/01/2016	Telephone	13:40
22	21/01/2016	Telephone	22:51
23	21/01/2016	Telephone	18:47
24	22/01/2016	Telephone	13:30
25	28/01/2016	Telephone	26:26
26	17/02/2016	Face-to-face	12:44
27	23/02/2016	Face-to-face	12:26
28	07/03/2016	Face-to-face	10:13

5.5.2 Demographics

The demographics of the interview subjects are outlined below.

Gender

There was a definite majority of men versus women (19 men, nine women), and while some areas of the Australian biotechnology sector are matched well in terms of gender balance, other subsectors are dominated by men. One female interview subject complained that she works 'in such a male-dominated field' (13 12:03), and on one business trip to Europe for a government agency she was the only female in a party of nine (13 12:14).

Location

Melbourne is recognised as the leading biotechnology hub for the Asia-Pacific region (Gilding 2008). Accordingly, most interview subjects were based in Melbourne, with Sydney a clear second. Although the author is based in Melbourne, recruitment was mainly done through the national AusBiotech conferences held annually, with one in the Gold Coast, another in Melbourne, and a third in Adelaide. The breakdown of interview subject locations is shown below.

Table 3: Interview subjects' locations

Location	Number of Interview subjects
Melbourne, Vic	15
Sydney, NSW	8
Central Coast, NSW	1
Brisbane, Qld	1
Gold Coast, Qld	1
Perth, WA	1
Adelaide, SA	1

Questions were taken from an informal list (refer to Appendix B), including discussion on the amount and nature of travel, geographical location of team members, experiences with jet lag, cultural and language issues, and performance; however, the content of the interviews was relatively unstructured, allowing topics of interest to be explored in detail. Additional written notes were taken during the interviews. There were technical difficulties with interview 04, and the comments were derived from notes taken. Interviews were analysed with initial coding according to themes, uploading a Word version of the interview transcript and uploading to *NVivo*.

5.6 Qualitative Phase Data Analysis

The interviews were transcribed into Word documents, and then uploaded into *NVivo*. Coding was done with the interviews, the codes were structured according to subject (Miles & Huberman 1994, pp. 57-62), and duplicate codes were amalgamated. During and after the coding process, themes were classified into major categories that were conceptual (Corbin & Strauss 2014), and themes were grouped into categories, e.g. the theme 'company culture' was placed as a subtheme of 'culture' (Miles & Huberman 1994, p. 62). Multiple codes per section of text were permitted, and occurred frequently, as material often related to multiple concepts. The interviewer's questions and remarks were coded, but not included in the final analysis. All material was coded except transcript material that was expressly deemed to be irrelevant (*e.g.*, greetings, sound check, *etc*.). Finally, similar themes were gathered into 'several overarching dimensions that make up the basis of the emergent framework' (Corley & Gioia 2004). Using the case study approach as outlined by Eisenhardt (1989) allows for *a priori* constructs, which in this study have been taken from the relevant academic literature.

Themes were then extracted from the interviews manually (as opposed to autocoding) using *NVivo* as first order concepts, which were then clustered into second order themes and then into aggregate dimensions, according to the methodology outlined in Gioia, Corley and Hamilton (2013) and Gioia and Thomas (1996), an example of which is documented by Gioia *et al.* (1994). The table of themes, in the categories of first order concepts, second order themes and aggregate dimensions is displayed in Figure 12 in section 6.2.

5.7 Quantitative Survey Methodology

The second phase of the study is a quantitative online survey using Qualtrics software. As with the qualitative phase, exclusion and inclusion criteria were applied to ensure that participants are currently or recently working in time zone disparate teams in the Australian biotechnology sector. This quantitative survey uses a 7-point Likert scale (strongly agree, agree, somewhat agree, neutral, somewhat disagree, disagree, and strongly disagree), with initial questions ascertaining that the informants meet the inclusion criteria. These questions centre on such themes as time zone disparity as a disruption to team performance, cultural measures, and management strategies. Examples of questions include 'having a greater than six-hour difference in time zones create problems for team performance' and 'dealing with English as a second language creates a barrier to effective team performance'. It was anticipated that 100 survey responses would be required for this second phase of data collection, and 153 were received, of which 147 were usable.

For the complete list of questions in the online survey, refer to Appendix C

5.8 Quantitative Survey Sample and Data Collection

Participants for the online survey have been gathered by networking events within the biotechnology sector, as well as word-of-mouth and email contact. As previously in the qualitative phase of the study, inclusion criteria for the survey are:

1. Currently working in the Australian biotechnology industry (*e.g.*, pharmaceuticals, medical devices, agriculture);
2. Be working or have recently been working with innovative (R&D) products; and
3. Be or have been part of or in charge of an internationally geographically dispersed team working with these innovative products.

These inclusion criteria were included in the first questions of the online survey (see Appendix C for the list of the online survey questions). Responses to the questions were completely anonymous. Data from the online survey was downloaded from the Qualtrics site for analysis. The survey participants were usually identified at biotechnology industry meetings, most commonly AusBiotech meetings (either the national conference or smaller state-based events), with a few from a digital technology group discussion on Meetup, and some by direct email from the AusBiotech membership list. In the later stages of data collection, participants were encouraged with $20 shopping vouchers and, for the AusBiotech conference in 2017 in Adelaide, 'chocolate frogs' were provided to encourage study participation. For most survey subjects, there was a short discussion on whether they were currently working or had recently worked as part of international teams that spanned multiple time zones, thus, the sampling was purposive (Hibberts, Johnson & Hudson 2012, p. 67). However, even without this direct contact, the qualifying questions at the beginning of the survey were used to screen participants who met the inclusion criteria for the survey, to avoid issues such as sample composition and data quality that can occur with internet-based surveys (Smith *et al.* 2016). There was a total of 153 people who participated in the online survey. Of these 153 survey participants, 147 responses were able to be analysed.

5.9 Questionnaire

The survey scale used for the quantitative phase of the study is that outlined by Hinkin (1995). Firstly, the items for the survey were generated from several sources. Several questions, particularly regarding the experiences of jet lag for participants were derived from the relevant medical literature. Many questions were taken from the interviews that had been conducted in the qualitative phase of the study (particularly around flights and class of flying, where there is a paucity of studies and academic literature). These questions were grouped deductively (with each survey question having a designated theme from the conceptual model), with the themes of the questions derived from the conceptual model developed in chapter 4 and the literature review in chapter 3 (Hinkin 1995), which allowed for multiple sources of information and data for the development of the survey questions (Hulland, Baumgartner & Smith 2018). The sources of the questions used in the survey are listed in the table below.

Scale development relied almost exclusively on Likert scales (using a numeric scale of 1 – 7, with 1 = strongly disagree and 7 = strongly agree, 4 being neutral). The only exception to this was the first two questions: question 1 asked for biotechnology sector, stage of development of the project being surveyed, team size and duration; and question 2 asked for the geographical regions of the interview subject, their team members to determine their time zones, with the time zone value from -12 – +12, corresponding to time zones UT -12:00 to UT +12:00.

Scale evaluation was performed to ensure the validity of the constructs, using Cronbach's alpha to validate for internal reliability of each construct derived from the questionnaire (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252; O'Shannassy & Leenders 2016).

The analysis of the quantitative data from the online survey was downloaded from the Qualtrics website as a CSV file and analysed with *SPSS* using multiple regression analysis (Brandimarte 2012, pp. 805-12; Bryman & Bell 2011, pp. 362-82). The kurtosis of the multivariate analysis was taken into account (DeCarlo 1997; Mardia 1970).

The list of references that each question was derived from is listed in the table below. The complete list of questions used in the survey is listed in full in Appendix C.

Table 4: Survey Questions and Sources Used

Question	Theme	Source
1	Team subsector, size, project	N/A (qualifying questions, subsector of biotechnology innovation)
2	Time zone differences within the team	N/A (details regarding team composition and location(s) and time zones)
3	Innovation	Muller and Peres (2017)
4	Team dispersion and communication	4.1, 4.4: Chudoba *et al.* (2005) 4.2, 4.3: interviews
5	Organisational culture	5.1, 5.2, 5.4, 5.6, 5.7: interviews 5.3, 5.6: Brett and Stroh (2003)
6	Flights	Interview data
7	Jet lag treatments	7.1, 7.2: Beaumont *et al.* (2004) 7.3, 7.13, 7.18: Arendt (2009) 7.4 – 7.8, 7.20: Sack (2010) 7.9: Waterhouse *et al.* (2007) 7.10, 7.12, 7.15, 7.19, 7.21, 7.23 – 7.26: interviews 7.11, 7.14, 7.16, 7.22: Revell and Eastman (2005) 7.17: Herxheimer and Waterhouse (2003) 7.27: Lemmer *et al.* (2002); Waterhouse *et al.* (2007)
8	Work-life balance, stress	8.1 – 8.3: Harrington (2001) 8.4: Westman and Etzion (2002)
9	Team dynamics	9.1 – 9.8: Maznevski and Chudoba (2000) 9.9: Chudoba *et al.* (2005) 9.10 – 9.13: Maznevski and Chudoba (2000)
10	Experience of jet lag for team members	10.1 – 10.5, 10.8, 10.9: Becker, Penzel and Fietze (2015b); Sack (2010); Spitzer *et al.* (1999); Waterhouse *et al.* (2007) 10.6: Czeisler and Fryer (2006) 10.7: Herxheimer and Petrie (2002)
11	Performance	Richard *et al.* (2009)
12	Geographical, cultural and language differences within the team	12.1, 12.9, 12.10: interview data 12.2: Tomasik (2013) 12.3 – 12.8: Chudoba *et al.* (2005)

5.10 Variables

5.10.1 Independent Variables

Similar questions from the survey were combined into variables (see Table 4). These variables have been categorised according to the model in section 4.5: namely, measures of performance, impact-mitigating behaviours that the participants engaged in to ameliorate the effects of temporal distance, and the team demographics. These variables were created using questions that were similar in meaning or intent and validated for internal reliability using Cronbach's alpha (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252; O'Shannassy & Leenders 2016)

A variety of impact-mitigating behaviours were examined, as well as factors that make virtual teams more difficult and possible strategies that companies could employ for staff who frequently travel. Challenges to temporally dispersed innovation teams include physical and cultural differences within the team. There were several approaches that management can take towards staff who travel frequently, and several impact-mitigating behaviours that those who work in teams across multiple time zones can employ.

Team characteristics

Stage of development is defined as where the project was at in terms of commercial development and had three options: early clinical / early development, late clinical / late development, and marketed products.

Average team size is the average number of participants on the nominated project team, entered directly as a number.

Team duration is defined as how long the project team was working together on the nominated project.

Physical distance is defined as the distance between team members in kilometres, as well as the number of time zones (Tomasik 2013). It was measured by three items in the questionnaire on physical and temporal distance: travelling in the same or adjacent time zones, flying north or south, and whether physical distance is a bigger problem than time zone differences. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .65, indicating good reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Cultural distance is defined as the distance between two cultures, as outlined by Hofstede (1984). It was measured by four items in the questionnaire examining cultural barriers to business, including team members finding some cultures difficult to deal with for business and 'hard to read', difficulties in communicating with team members in other cultures, and finding that cultural differences were a challenge. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .87, indicating excellent reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Impact-mitigating behaviours

Medical approach is defined as the medical issues that arose for business travellers and the medication that was taken to alleviate it (Sack 2010; Samuels 2012). It was measured by three items in the questionnaire which were about prescribed medication, melatonin, and complaints about travel. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .64, indicating good reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Time management is defined as strategies around time management and early arrival (Sack 2010). It was measured by three items in the questionnaire, covering difficulties in attending morning meetings, arriving early, and going shopping. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .58, indicating acceptable reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Tips & tricks is defined as simple measures business travellers use to alleviate jet lag (Herxheimer & Waterhouse 2003; Sack 2010). It was measured by five items in the questionnaire including sunlight, diet, exercise, and adequate hydration. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .61, indicating good reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Circadian adjustments is defined as the use of light therapy or adjusting the schedule when they travel across multiple time zones (Cingi, Emre & Muluk 2018; Eastman & Burgess 2009; Phipps-Nelson *et al.* 2009; Regente *et al.* 2017; Sack 2010; Zee & Goldstein 2010). It was measured by four items in the questionnaire examining light therapy and daily scheduling. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .74, indicating very good reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Temporal organisational approaches

Laissez-faire is defined as an approach where managers have a 'hands off' approach to managing a team that spans multiple time zones (Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007). It was measured by four items in the questionnaire where team members are expected to 'push through' fatigue and work outside working hours. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .74, indicating very good reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

'Concentrate the pain' is defined as having a mechanism where most of the burden of working across multiple time zones is borne by a select number of designated employees (Welch, Welch & Worm 2007). It was measured by three items in the questionnaire by looking at whether there were designated business travellers, and whether they were Australian. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .64, indicating good reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

'Set the boundaries' is defined as having organisational-level policies in place to ensure workers in teams that spanned multiple time zones were managed accordingly (Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007). It was measured by three items in the questionnaire looking at workplace procedures and delegation of travelling staff. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .60, indicating good reliability (Aiken &

Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Having discussed the independent variables in this study, the dependent variables are now outlined.

5.10.2 Dependent Variables

The dependent variables in this study were all related to performance, with three measures of performance used, two of which were project-based (the financial performance of the project and its technological performance), and one was physical performance, examining the physical effects from working across multiple time zones with the resultant late nights, early mornings or jet lag.

Financial performance is defined as a measurement of the product's financial outcomes (Baum, Calabrese & Silverman 2000). It was measured by eight items in the questionnaire using quantifiable financial measures such as market share growth, growth in sales, return on equity (ROE), return on sales (ROS) return on assets (ROA), and return on investment (ROI) which are used to determine financial performance (Saeidi *et al.* 2015), as well as how well a company uses its assets and investments to generate earnings and market performance (Post & Byron 2015), capturing components of the organisation's financial performance (Richard *et al.* 2009). Quantifiable financial measures that can be reported by innovation project team members such as meeting sales volume goals, meeting or exceeding revenue targets, profitability, market share, sales volume and break-even point were all surveyed. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .92, indicating excellent reliability (Aiken

& Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Technological performance is defined as the success of the technology of the project that was worked on (Baum, Calabrese & Silverman 2000). It was measured by four items in the questionnaire including functionality, performing to specifications, meeting quality guidelines and overall success, with two key dimensions are efficiency and efficacy (Curado, Muñoz-Pascual & Galende 2018; Neely, Gregory & Platts 1995). Performance gaps and technological alternatives can be used to identify feasible target technological performance metrics (Lee, Kim & Shin 2017). This measure allowed not only the organisation's financial performance to be measured, but the organisation's effectiveness in terms of operations and product (Richard *et al.* 2009). An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .81, indicating excellent reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Physical performance is defined as the ability to perform duties despite difficulties posed by working in teams across multiple time zones (Becker, Penzel & Fietze 2015a, 2015b; Spitzer *et al.* 1999; Waterhouse *et al.* 2002). It was measured by six items in the questionnaire, examining cognitive function as well as mood and wakefulness. Jet lag assessment typically uses self-reporting rather than objective data measurement (Becker, Penzel & Fietze 2015a; Ruscitto & Ogden 2017; Sieberichs & Kluge 2018). Accordingly, survey participants were asked about mood impairment, lack of clarity in thought, memory issues, light-headedness or dizziness, and daytime drowsiness. An exploratory factor analysis showed that there was one underlying dimension (Tabachnick & Fidell 2007, pp. 609-15), with a Cronbach's alpha of .85, indicating excellent reliability (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252). The full list of items in this variable are listed in table 5.

Having constructed the questionnaire from a combination of interview data and relevant literature, variables were created based on combinations of similar questions. As discussed, two main categories of variables were measured: the independent variables, which included team characteristics (the nature and duration of the team, physical and cultural distances within the team), impact-mitigating behaviours to offset the negative effects of working in teams that span multiple time zones, and temporal organisational approaches (designated as *laissez-faire*, 'concentrate the pain' and 'set the boundaries'); and dependent variables, which included the measures of performance (financial, technological and physical). The complete list of variables and the questions they were derived from is given in Table 5 below. From the intervariable correlation table presented in Table 10, it shows that the intervariable correlations between the independent variables are relatively low. This provides a good opportunity for a multivariate analysis and offers support for adequate discriminant validity across constructs.

Table 5: Variables Measured

Item	Items / Questions
Team characteristics	
Stage of development	1.2 Please select which stage of development your team is/was working in
Average team size	1.3 What was the average size of this team (number of people) over the duration of this project?
Team duration	1.4 How long did the project team last? (years)
Physical distance	12.1 The majority of the team's travel is within the same or adjacent time zones 12.2 In my team most of the flying is fly north-south 12.3 Physical distance is a bigger problem than time zones
Cultural distance	12.4 Members of my team find some cultures difficult to deal with for business 12.5 Team members in different cultures can be 'hard to read' 12.6 The majority of my team find communication with other cultures difficult 12.7 Cultural differences are a big problem in my team

Item	Items / Questions
Impact-mitigating behaviours	
Medical approach	7.7 Team members take prescribed medication (not including melatonin) for jet lag when they travel 7.8 Team members take melatonin when they travel 7.23 Team members complain a lot about travel
Time management	7.19 It is difficult for members of my team to attend morning meetings when travelling 7.21 Team members like to fly in early to destinations 7.24 Team members go shopping to alleviate jet lag
Tips & Tricks	7.5 Team members use sunlight when they travel 7.9 Team members exercise to prevent jet lag 7.13 Team members drink plenty of water when they fly 7.17 Team members maintain a healthy diet when they travel 7.20 Team members use daylight to adjust to different time zones
Circadian adjustments	7.6 Team members use light therapy when they travel 7.14 Before team members travel across time zones they adjust the time they wake up and go to sleep 7.16 Team members adjust their schedule before leaving on an overseas business trip 7.22 Team members adjust their daily pattern to the new time zone before they fly

Item	Items / Questions
Temporal organisational approach	
Laissez-faire	5.2 Team members are expected to 'push through' fatigue and jet lag 5.4 Team members work longer hours when they travel 5.7 Team members often fly outside working hours 5.8 Team members often Skype outside working hours
'Concentrate the pain'	5.9 There is a select group of team members who travel a lot across time zones 5.10 In my team, Australians are more prone to fly overseas than other nationalities 5.11 Some people in my team are specifically hired to undertake a lot of travel
'Set the boundaries'	5.1 There is someone who covers a team member's work when they travel 5.3 There are processes in place to ensure team members do not work too many hours 5.13 There are members of my team that cover the travel burden

Item	Items / Questions
Team performance	
Financial performance	11.11 The team’s product met its sales volume goals 11.14 Our team is likely to hit its revenue targets 11.17 The products or services my team developed exceed revenue targets 11.18 The products and services my team developed are very profitable 11.19 The products or services my team developed meet market share goals 11.20 The products and services my team developed met its year 1 market share goal 11.21 The products and services my team developed meet its sales volume goal 11.23 Our product(s) the team developed reached break-even earlier than expected
Technological performance	11.1 The technology my team developed is very functional 11.5 The product(s) the team developed performs to specifications 11.7 The product(s) the team developed met quality guidelines 11.12 The team has been recognised as being very successful
Physical performance	10.4 Team members experience impaired mood when they travel 10.5 Team members are unable to think clearly for a day or two after travel 10.6 Team members have trouble with memory when they travel 10.7 Team members experience light-headedness or dizziness when they travel 10.8 Team members are drowsy during the day when travelling for business 10.9 Team members have trouble concentrating or thinking clearly when they travel

The results that have been derived from these variables are presented in full in chapter 7.

5.11 Analysis

Regarding the variables that were created, descriptive statistics were outlined from *SPSS* and analysing for kurtosis. Exploratory factor analysis was undertaken in relation to the data, and having established the factors, internal reliability of these factors using Cronbach's alpha was ascertained (O'Shannassy & Leenders 2016).

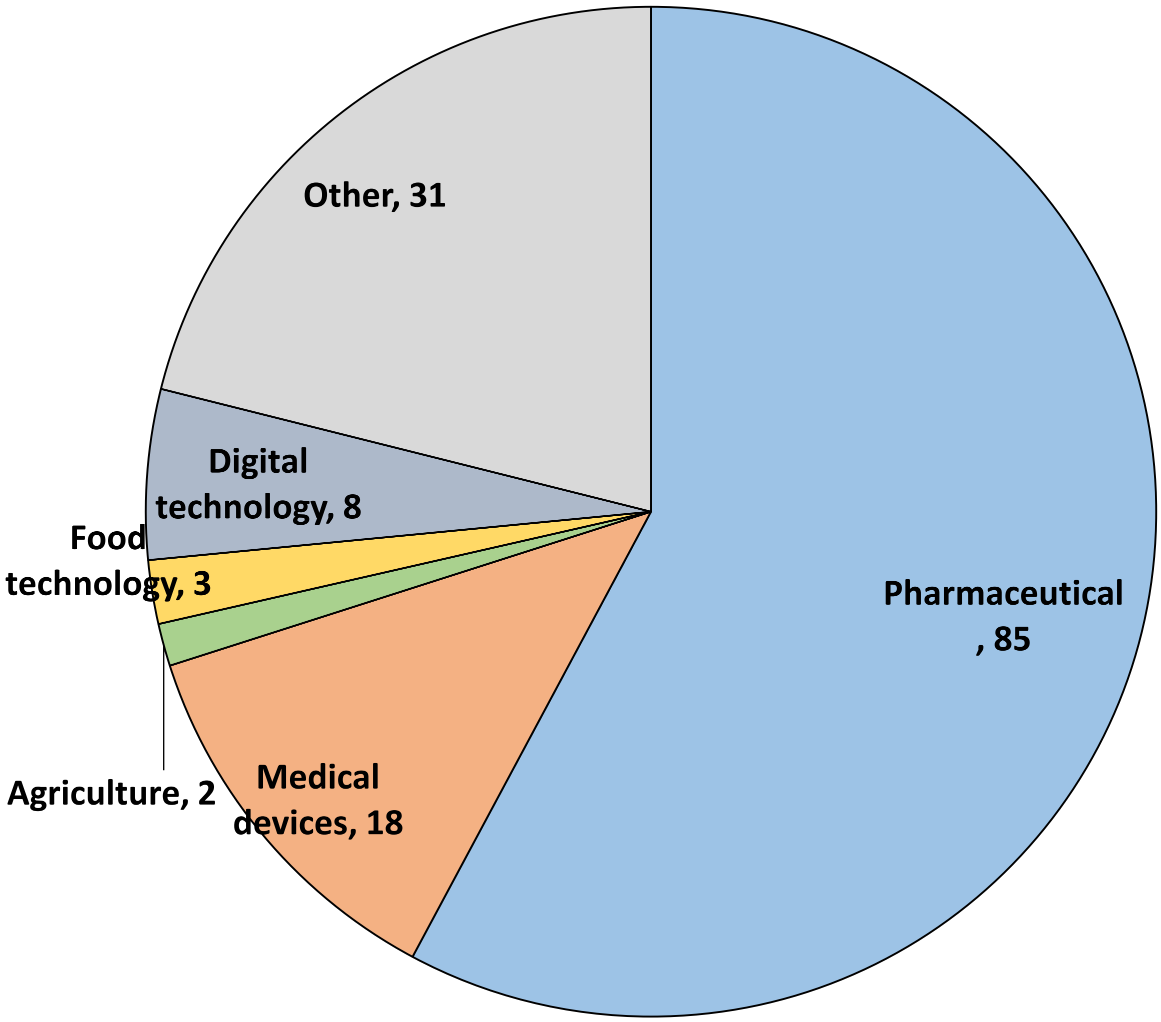
The bivariate correlations between these factors were tabulated, and then multiple regression using *SPSS* was performed with the dependent variables (the three measures of performance: financial, technological and physical) to determine significance (Bryman & Bell 2011, pp. 362-82; O'Shannassy & Leenders 2016). The results of this analysis are discussed in chapter 7.

5.12 Response Sample

5.12.1 Industry Sector

The biotechnology sector comprises of a number of subsectors including pharmaceuticals, medical devices, agriculture, food technology, digital technology and energy production (EuropaBio 2013; Kafarski 2012). Question 1.1 asked the participants which one of these categories their work was aligned to, along with an 'other' category. There were no respondents who stated that they worked in the energy sector in this survey. The participants who selected 'other' included the following elements: government agencies, education, venture capital, clinical research or clinical trials, commercialisation, speciality logistics, industry association, service providers, imaging, software, molecular biology and genetics, intelligence, media, those who worked with both pharmaceuticals and medical devices, and those who reported as working with all the sectors. These are outlined in the chart below.

Figure 7: Industry Sectors

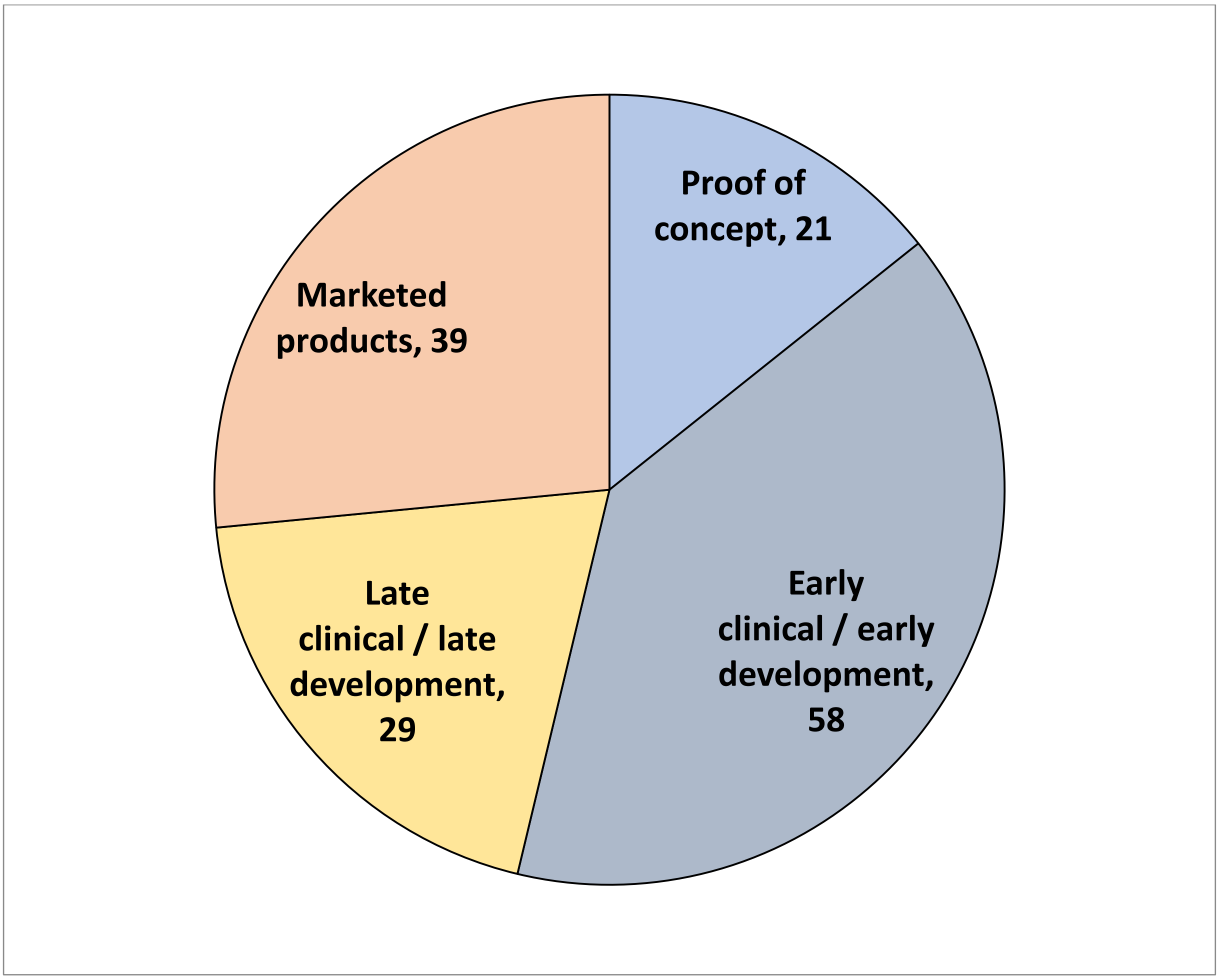


Pharmaceuticals dominated the demographics with just over half (56%) of respondents, followed by medical devices. There were few survey participants from the agricultural and food subsectors, and none from the energy subsector. There was quite a large contingent of 'other' participants as previously described, indicating the Australian biotechnology sector is a complex ecosystem with many actors who cannot be readily categorised by the type of biotechnology used.

5.12.2 Stage of Development

The innovation of new products goes through a number of stages (Davids & Frenken 2018), from proof of concept through to the product being marketed. The stage of development was asked in question 1.2, and while the early stages of development dominate, there is a reasonable mix of stages in the survey cohort. The stage of development that the respondents work in is outlined in the table below.

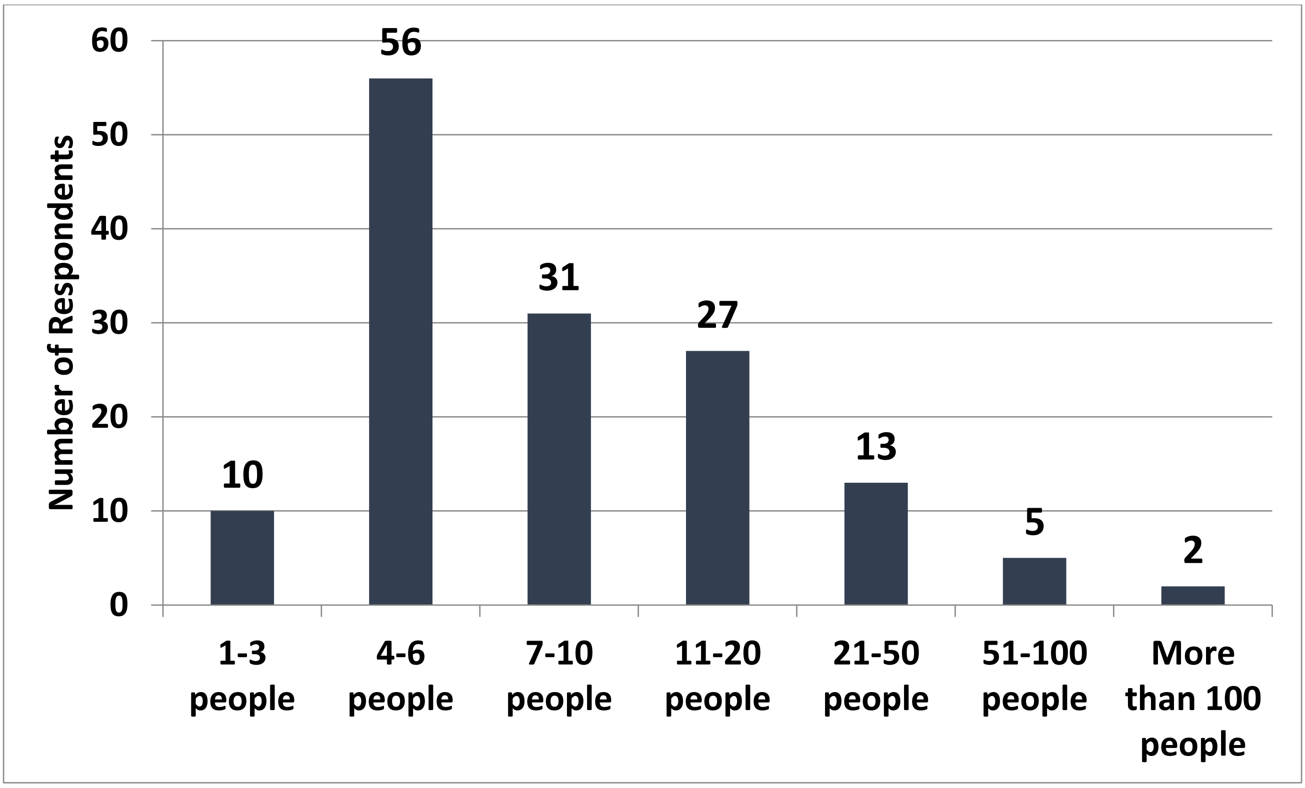
Figure 8: Stage of Development



5.12.3 Team Size

Participants were asked about the size of the team that they were reporting on in question 1.3 of the online survey. The average team size was 17.4 team members, although this was most likely skewed by a small number of teams with a large size (more than 100 people). The geometric mean of the team size was 9.2 participants, although the graph below shows a definite peak with 56 teams (38% of the sample) containing 4 – 6 members. The distribution of team size is shown in the graph below.

Figure 9: Team Size

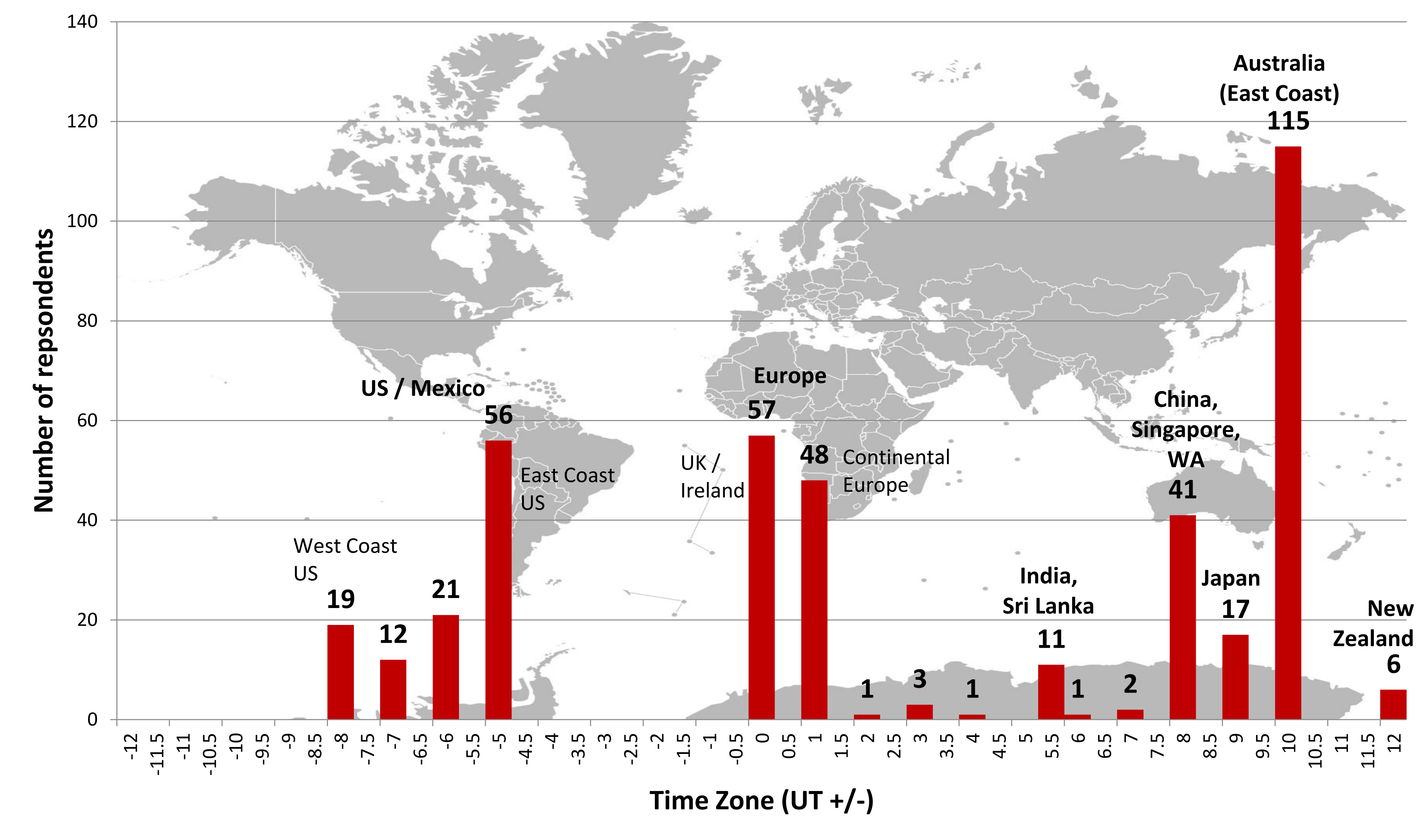


5.12.4 Spread of Time Zones

To get an idea of where team members were located, survey participants were asked where their fellow team members were in question 2.2. The number of team members was severely skewed by one response that reported 8,500 team members in China. Therefore, what was counted was the number of respondents who had team members in various time zones. The time zones selected were categorised into three main categories: Asia-Pacific, Europe, and North America, with an 'other' category available. The time zones specifically requested were Australia (except WA) (UT +10), Japan, South Korea (UT +9), China, Singapore, and Western Australia (UT +8), United Kingdom, Ireland (UT 0), Continental Europe (France, Germany, etc.) (UT +1), US / Canada East Coast (UT -5), US / Canada Central Zone (UT -6), US / Canada Mountain Zone (UT -7), and US / Canada West Coast (UT -8).

These other countries listed by the participants were India, Israel, Kazakhstan, Mexico, New Zealand, South Africa, Sri Lanka, Thailand, United Arab Emirates, and Vietnam. These 'other' category countries were also categorised according to their time zone. Mexico was categorised with US Central standard time due to being in the same time zone (UT -6), and Sri Lanka and India were combined (both nations are on UT +5:30), and similarly Thailand and Vietnam were combined (both nations are on UT +7). Several responses could not be categorised by time zone: 'Meena' (presumably Middle East and North Africa, covering a range of time zones), 'Partner lab/CRO [contract research organisation]' and 'Clients from anywhere'. There was a higher than anticipated response for India (ten responses, plus an additional one from Sri Lanka), New Zealand (six responses), and Israel (three responses), which was not predicted from the interview phase of the study. The numbers of respondents with team members in various time zones is listed in the graph below.

Figure 10: Respondents with Team Members in Time Zones



The results showed firstly, an overwhelming dominance of respondents having team members on the eastern seaboard of Australia. Secondly, it is obvious that there are clusters of partnership, particularly the US East Coast (with a much greater time zone difference to Australia than the US West Coast), the United Kingdom and continental Europe dominating. Some Asia-Pacific nations were represented, particularly China / Singapore. Lastly, there were unexpectedly high numbers of partnerships with India, New Zealand and Israel, as well as a few other Asian nations.

5.12.5 Summary of Response Sample

In this sample of Australian biotechnology workers who worked in team spanning multiple time zones, pharmaceuticals were by far the largest subsector represented (56% of the total), although most other subsectors named were also represented in the sample except for the energy subsector in biotechnology, which appears to be limited in Australia. Many participants could not be readily categorised into a biotechnology subsector, either because they worked across boundaries or had a function that supported them such as venture capital or media, indicating that the biotechnology industry in Australia is a complex ecosystem with a variety of agents.

In terms of stage of development, early development is strongly represented, although all stages of development from proof of concept through to marketed products are all included in the online survey sample.

Survey participants were mostly part of teams with 4 – 6 members, with the average of 17.4 team members and geometric average of 9.2 participants skewed by a small number of teams with large numbers of people.

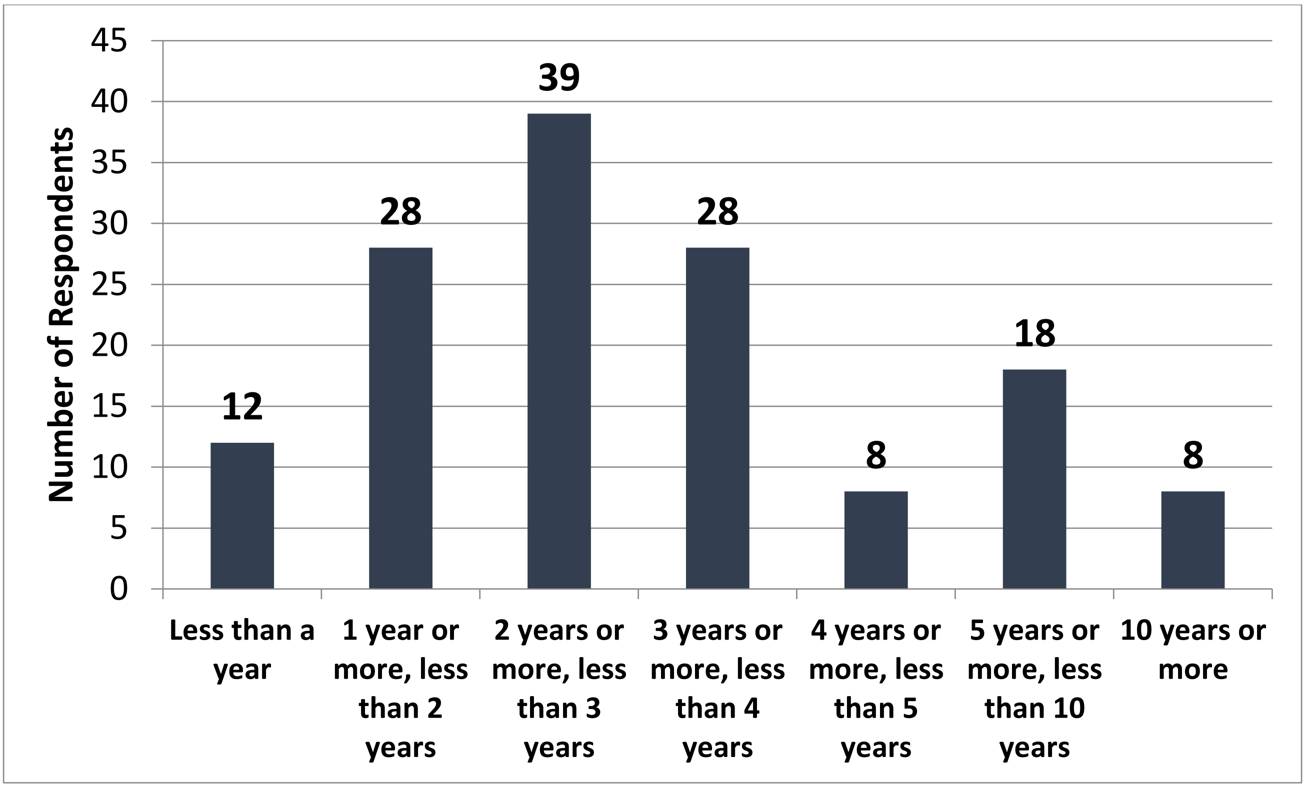
The average team duration that participants reported was 3.0 years (geometric mean 2.2 years), which aligned with the high number of respondents reporting teams that lasted from two to three years.

Finally, regarding time zones there were obvious clusters that survey participants identified, with the Australian eastern seaboard strongly shown, as well as the United States, the United Kingdom, China / Singapore, and to a lesser extent India, New Zealand and Israel.

5.12.6 Team Duration

The participants were asked about the duration of their project team in question 1.4. One outlier response of ‘700 years’ was discarded as an obvious error. Having discarded this one data point, there was an average of 3.0 years and a geometric mean of 2.2 years for team duration. This matched the high number of respondents reporting teams that lasted from two to three years (27% of sample, see graph below). While there were a few teams that lasted longer than five and even ten years, this did not appear to particularly affect the data. The number of respondents and the team duration are plotted in the graph below.

Figure 11: Team Duration



5.13 Summary

The methodology of this study is based on the ontology of critical realism, where structures at work in the social world need to be identified, and are not immediately apparent (Bhaskar 2010, p. 2). Accordingly, the epistemology is inductive, using a case study approach (Eisenhardt 1989). The methodology was mixed method, with a qualitative interview phase with 28 interview subjects to extract the themes and identify the structures at work, followed by a quantitative phase with an online survey of 153 subjects, with multiple Likert scales to quantify the measures identified in the qualitative phase.

Study participants were recruited through industry events and were screened in each phase to ensure that they were currently working or had previously worked in innovation teams in the Australian biotechnology industry that encompassed multiple diverse time zones. In the interview phase, it was a simple matter of asking the participant before the interview to ensure that they met the study criteria. Some interviews were conducted face-to-face, although most interviews were conducted by telephone, as many interview subjects either had time constraints or were based interstate. The validity of telephone interviews has been affirmed from a multiple studies (Drabble *et al.* 2015; Mahfoud *et al.* 2014; Vogl 2013). The telephone interviews in this study were checked by two senior academics for quality.

For the online survey, subjects were asked which sector of biotechnology their team is or was working in (question 1.1) to identify them as being qualified to complete the survey.

For the qualitative interview phase of the study, the interviews were transcribed and manually coded using *NVivo*, as the autocoding function of *NVivo* was not used in this study. Codes were identified as first order concepts, then condensed into second order themes and aggregate dimensions (Gioia, Corley & Hamilton 2013; Gioia & Thomas 1996), in line with the model of performance that had been constructed from the relevant academic literature (Eisenhardt 1989).

From these interviews, survey questions were derived and combined with questions derived from the academic literature (listed in Appendix C). Interview questions with a common theme were combined to create variables (Table 4), with these variables divided into the categories of performance measures, impact-mitigating behaviours, and team demographics, with the ultimate purpose of measuring the effect of time zone differences on performance, and the various measures used to offset this. This was done with regression analysis using *SPSS* to analyse the data (Bryman & Bell 2011, pp. 362-82). Finally, the data were analysed, and the results of the quantitative analysis are presented in chapter 7 and are discussed in chapter 8.

A convenience sample was used, in which total of 153 participants took part in the online survey, of which 147 responses could be used. Participants for the online survey were located by networking events within the biotechnology sector, as well as word-of-mouth and email contact.

Online survey questions came from a variety of sources: some from the relevant academic literature (particularly those relating to jet lag), and some from issues that were raised in the interview phase of the study.

With the questionnaire several variables were constructed, in three categories: measures of performance, impact-mitigating behaviours, and team demographics. The impact-mitigating behaviours included the categories '*laissez-faire*', 'concentrate the pain' and 'set the boundaries', which were management responses to the staff members working on teams that spanned multiple time zones.

The pharmaceutical subsector was strongly represented, although all subsectors except energy were represented, with several respondents unable to self-categorise, indicating complexity in the Australian biotechnology ecosystem. Early development was favoured in terms of stage of development. Participants were frequently part of teams of 4 – 6 members, and team duration was typically 2 – 3 years. Teams frequently collaborated with the US, particularly the East Coast, as well as Europe and the United Kingdom, as well as smaller responses from nations in the Asia-Pacific region.

Having outlined the methodology and research design for this study, this report now presents the results from the qualitative phase of the study, which was the data extracted from 28 interviews.

6. Interview Results

6.1 Introduction

Chapter 6 outlines the findings from the qualitative data, which were used to determine the concepts and factors that would be assessed in the quantitative phase of the study, using Likert scales that were informed by the interview data (Bryman & Bell 2011, p. 634; Carpenter *et al.* 2016). This method of using the qualitative data to build on subsequent quantitative research was the reason that the mixed method approach was selected for this study (Hallebone & Priest 2009, p. 66).

The data for the qualitative phase of the study was taken through a series of interviews of approximately 30 to 60 minutes in duration (Hackley 2003, p. 119), with audio recording. Interview transcripts were made and uploaded into an *NVivo* database, which supports qualitative research (Maher *et al.* 2018). Themes were identified from the NVivo database as first order concepts, which were then combined into second order themes and finally into aggregate dimensions, using Gioia's methodology (Corley & Gioia 2004; Gioia, Corley & Hamilton 2013; Gioia & Thomas 1996; Gioia *et al.* 1994) (refer to Figure 12 below).

There was a total of 28 interviews conducted in the qualitative phase of the study, and this chapter presents the results. Firstly, the key phrases that were volunteered by the interview subjects are noted, looking for underlying themes to inform the analysis, using open questions (Quinlan 2011, p. 293). Of the 28 interviews, 19 were conducted by telephone, which has provided similar results in qualitative research (Drabble *et al.* 2015; Mahfoud *et al.* 2014; Sturges & Hanrahan 2004; Vogl 2013). The various forms of distance (temporal, physical, cultural and language) are discussed with reference to workers in globally dispersed teams. The nature and location of these teams is discussed, noting which nations or clusters of nations are prominent. Impact-mitigating behaviour is then examined, looking at the amount of travel participants undergo, the benefits and importance of having face-to-face contact with fellow team members in remote locations, strategies used to address jet lag, the importance of flexibility in the workplace, particularly in terms of working hours, and communication strategies to overcome the large distances that separate teams.

The various aspects of performance that is potentially impacted by participating in globally dispersed teams is assessed, including the measurement of this performance, the impact on logistics (particularly within the Australian context), and the effect of travelling and / or long hours on cognitive function in team members.

6.2 Key Phrases

Three phrases that were spontaneously and frequently used by the interview subjects are discussed below.

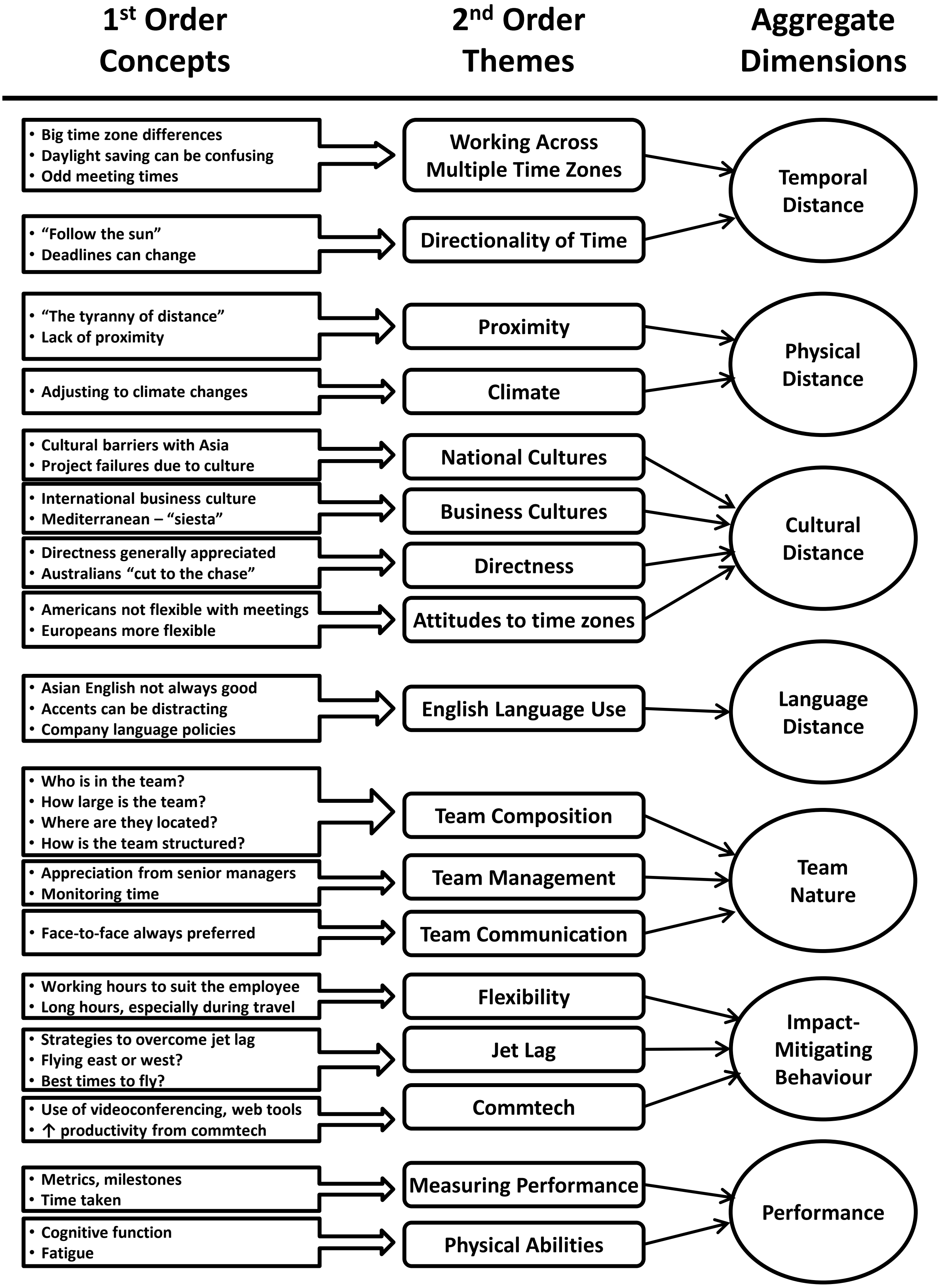
'Tyranny of distance' (01 01:44; 22 16:17, 17:31) is derived from the title of Geoffrey Blainey's 1966 book which examined Australia's isolation from the rest of the world (Blainey 1966), and has 'become embedded in the national psyche' (Wood 2007). The use of this phrase conveys a sense of isolation and remoteness that interview subjects experience, with one interview subject even proposing the humorous but impractical solution of moving Australia further north to near Hawaii (25 26:00).

The second phrase repeatedly generated from the interviews was 'running on adrenaline' (02 18:15; 06 05:15; 15 08:30; 17 12:43). One interviewee stated that adrenaline was useful for focus (17 12:32; 13:08), and another that it was the best cure for their jet lag (10 11:45). Many interview subjects reported a sensation of exhaustion on return to Australia: 'it's probably adrenaline that keeps you going in one direction, and as you arrive back and the adrenaline's over because the big meetings are done, then you sort of land at home and maybe take it easy for a day or so' (24 11:35), and another interviewee said 'if you've got long-running days of late nights, having to work late nights, then you don't seem to notice it because you've got things you need to do. But it does kick in once it's all done and dusted, once the adrenaline has dropped off' (17 11:47), and another, 'you have to keep driving yourself to get up to attend meetings, to – you know, accept the three o'clock in the morning wake up, you start your day at three o'clock in the morning essentially… you're driven largely by adrenaline… I think you kind of store up all that need for sleep and then you end up trying to catch it up when you get back' (25 06:46).

The third phrase, 'pushing through', or related phrases such as 'soldier on' were used by several interview subjects, as they described their experience of pushing through fatigue while traveling and refusing to rest during the daytime (13 20:05; 15 07:29; 19 14:32).

Analysing these three phrases, the first phrase 'the tyranny of distance', reflects a sense of physical isolation or remoteness in Australia (Gilding 2008). The second phrase, 'running on adrenaline', refers to a sense of exhaustion in workers in this sector, from travel or long hours, and the use of the word 'adrenaline' was reported by a quarter (seven out of 28) of the interview subjects. The phrases 'soldier on' or 'push through' also relate to a sense of exhaustion commonly experienced by many of the interview subjects. The temporal distance (the difference in time zones) that underpins this isolation will be discussed. The model of team distance including temporal distance (Figure 4) is used as the outline for the qualitative analysis below.

Figure 12: Data Structure as per Gioia, Corley and Hamilton (2013)



6.3 Team Characteristics

6.3.1 Basic team characteristics

The size of dispersed innovation teams varied considerably, with the number of team members ranging from a low of six (08 00:45) through twenty (02 02:09), and up to fifty (12 16:05). As described earlier, innovation teams that spanned a range of time zones typically had members in Australia, the United States and Europe. Within these teams there appeared to be a level of management where the bulk of the travelling fell. Subordinate managers were typically based in a single region, with a 'matrix-style organisation' (07 00:30), while the manager travelled across multiple time zones (05 01:14; 28 03:46). Some roles were deliberately crafted to include a high degree of travel ('project leaders, there's a lot more travel for them' 12 02:29; 'we have one BD [business development] guy who's based in the UK whose job is to travel' 25 07:46), and support engineers who travelled a lot, with regional-based teams reporting to them (07 10:13), 'management were travelling and then local teams were staying in place' (07 10:42). Above the management level of those who travelled, however, there could be another layer of senior management that did relatively little travel. One interviewee reported that they reported to senior management who neither travelled nor seemed to particularly appreciate their efforts: 'unless people do it, as in senior management, unless they've done it, then they're not going to necessarily appreciate what's required to get things done' (19 16:29).

Not all teams required a lot of travel, however, with some functions reported to require less travel (10 18:44; 11 02:58; 11 21:40).

A few key factors of the nature of innovation teams dispersed across multiple time zones were uncovered in the interviews. Firstly, there was the question of who travels: in some interviews, there appeared to be a layer of management that could be dubbed the 'frequent flyer card' level, with team members below this level rarely, if ever, travelling outside their region, while management above this level only occasionally travelled across multiple time zones, preferring to be mainly based at head office. Secondly, the degree of virtuality among dispersed teams varied considerably and appeared to vary with function, with some subsectors using mainly electronic communication, and some projects requiring relatively little team contact. Finally, appreciation from senior management for the amount of travel and long hours worked may be a factor in job satisfaction. These factors will be explored further in the quantitative analysis segment of the study. Having examined the nature of the dispersed innovation teams, this analysis now turns to the impact-mitigating behaviour used by team members to ameliorate the worst effects of temporal distance.

6.3.2 Physical & temporal distance

Physical and temporal distances are closely linked (Christen 2017; Tomasik 2013), and this section addresses both forms of distance, first physical distance, then temporal distance.

As noted previously, physical proximity is a positive factor in scientific collaborations (Abramovsky & Simpson 2011; Kabo *et al.* 2014), and the phrase 'tyranny of distance' indicates a sense of isolation.

According to the interview subjects, in some instances proximity was deemed absolutely necessary: 'if I was supervising a project where, say, there was a lot of bench work in the lab, you would really have to be in close proximity to see what was going on' (02 11:44); with the lack of proximity, another reported that communication was 'constrained to teleconferences' (06 03:29). However, not all interview subjects felt that losing proximity was a significant issue (02 08:44); 'as long as the job's done, it doesn't matter where you do it' (07 17:17).

The sense of geographical isolation, relating back to the phrase 'tyranny of distance', discussed earlier, was noted by a couple of subjects: 'I'm the least connected part of the team… because you're just not there, so they have so many meetings that I'm not part of... there's a lot you don't know, not being present' (10 19:00). One subject found the restriction to teleconferences because of isolation rather constraining: 'you could occasionally pick up a phone, but – you know, with different time zones you can't just, think of something 'oh yeah, I'll call such and such' because they're not going to be at work. I think you're confined to teleconferences, generally speaking' (06 03:30). The sense of isolation was also noted by one interview subject who had moved to Australia from Europe: 'when I moved to Australia, it's like – you feel like you're falling behind, because suddenly you're disconnected' (07 18:46).

Physical remoteness and isolation is clearly a significant factor in the experience of workers in the Australian biotechnology sector. While there have been substantial advances in communication technology, the added factor of temporal distance compounds what would otherwise be a difficult connection to maintain.

This remoteness affected travel routines, and when visiting colleagues overseas, combining travel destinations due to cost and time savings was a popular strategy, (03 08:16; 06 09:30). A couple of interview subjects noted that Australians were unwilling to travel, with one talking about Australian business people unwilling to get on a plane to fly overseas (07 19:29), and another stating 'we don't like to travel that much. We think that we are… too precious and we don't like – we actually don't like physically relocating… I think we're spoilt. If you go to America or England it's quite, quite often you'll find a person who owns a home in one town working in a completely different time zone… it's just something that we haven't, as a culture, accepted' (01 01:30).

As discussed, the temporal distance (calculated as the difference in time zones) between Australia and most of the partner nations for projects is significant. The largest single nation for collaboration is the United States, and the chart below shows that European and Asia-Pacific nations were also well-represented in teams that spanned across multiple time zones. Partner nations of interview subjects are listed below.

Figure 13: Partner nations identified by informants (pie chart)

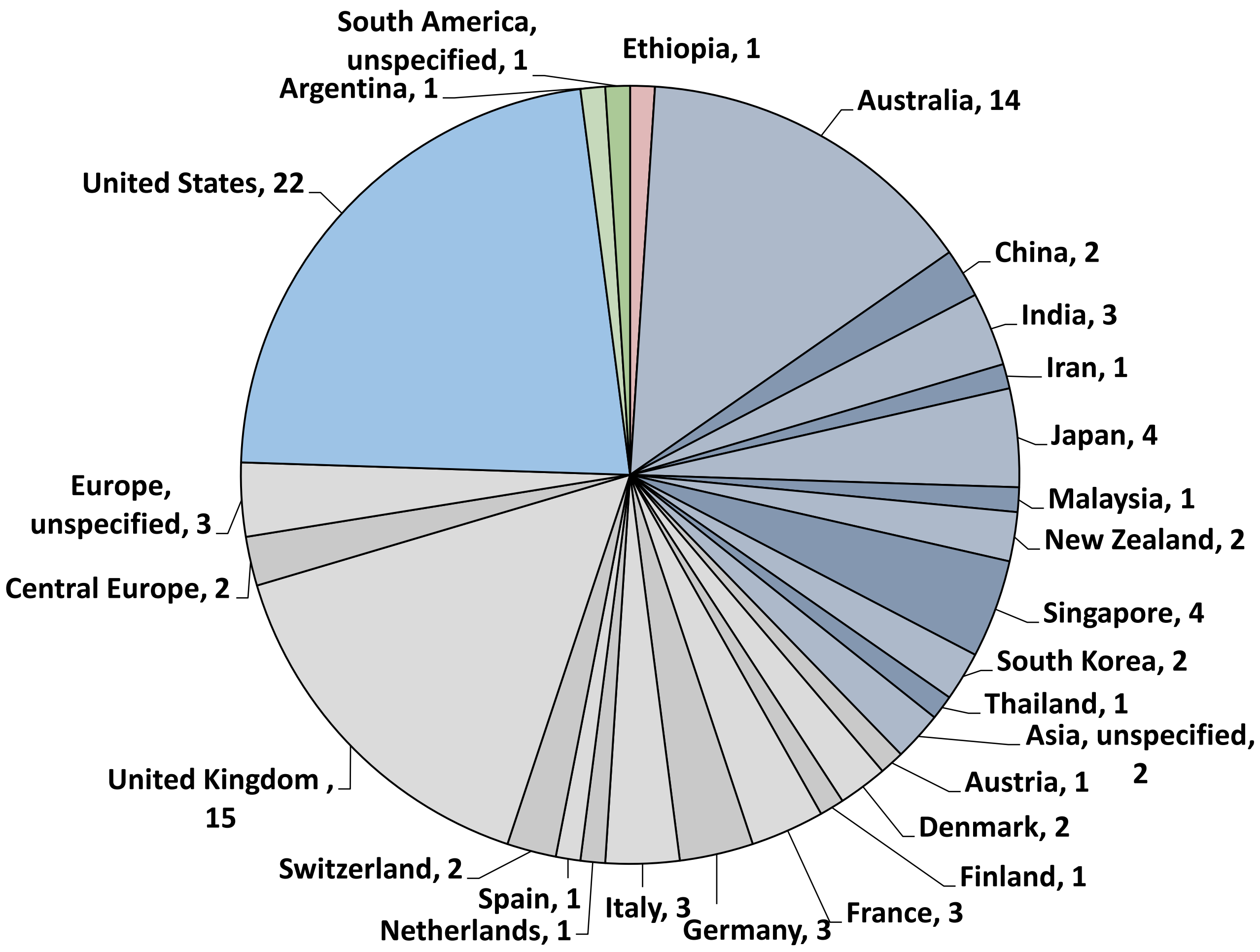
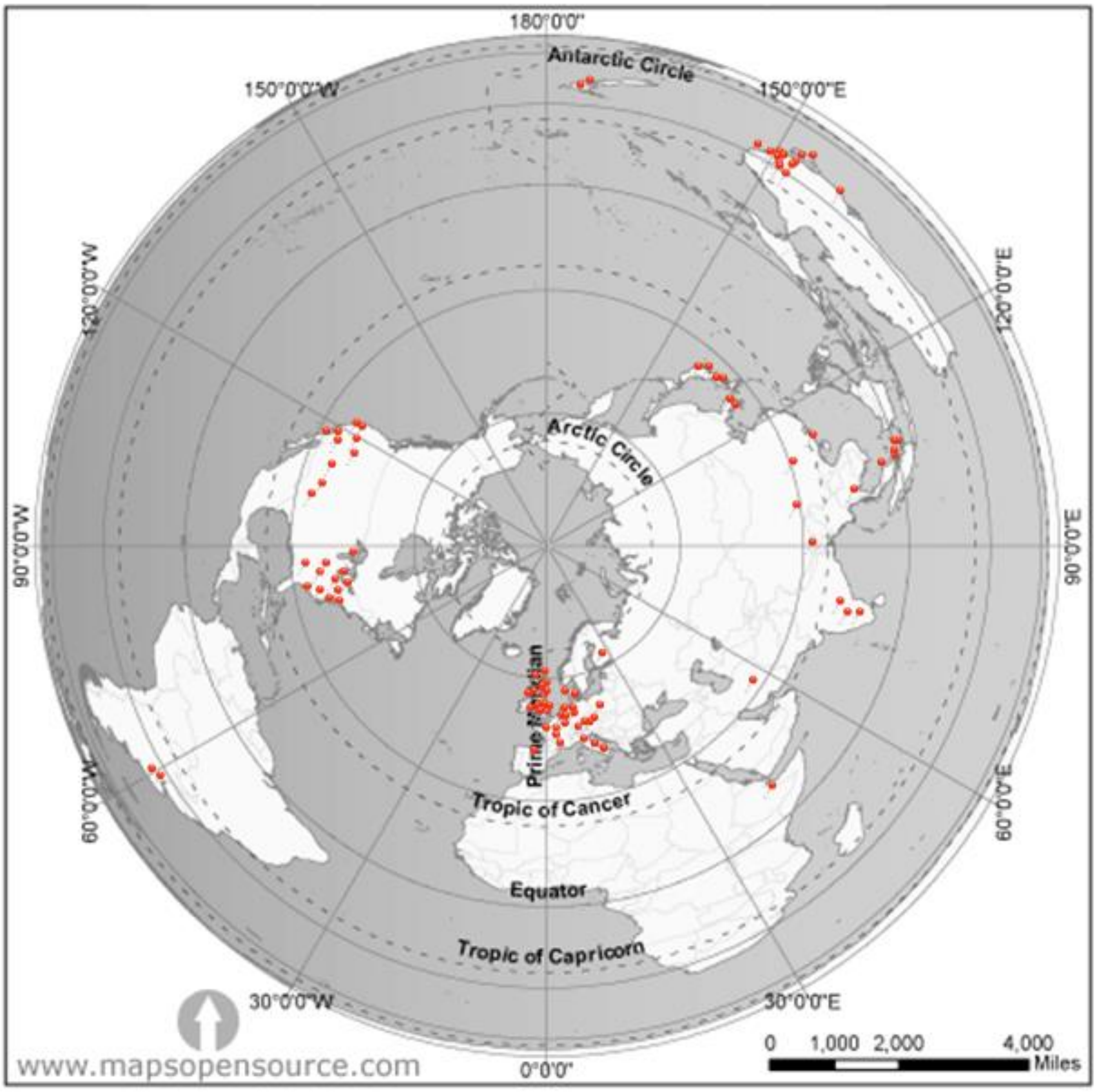


Figure 14: Partner nations identified by informants (map)



Almost all the interview subjects reported substantial time zone differences within their teams, typically involving the United States (US) and / or the European Union (EU) (01 00:45; 02 00:45; 03 03:00; 06 00:18; 08 01:14; 09 01:15; 10 00:31; 11 01:28; 12 00:15; 13 25:10; 14 00:29; 15 00:15; 16 00:29; 17 00:29; 18 00:17; 19 00:30 20 00:28; 21 03:33; 22 09:15; 25 00:30; 27 00:29). One of the most extreme cases of time zone variation was a project where 'the main countries involved would have been the US and the EU, South America, Australia' (12 00:29), and another interview subject's company had hubs in Melbourne, Shanghai, Cambridge (UK) and San Francisco (25 00:32). Because of the time zone disparities, early morning or evening meetings were common for Australians working in this sector (23 01:59; 28 04:59; 27 04:00), and some subjects had meetings at very difficult times, 1 a.m. (17 05:17) and 2 a.m. (14 05:52).

Most participants noted that Australians tended to work out of business hours more than team members from other nations: 'generally Australians have to take the hit and are more likely to travel or have to work outside of hours' (08 16:20); 'inevitably, Australia's at the wrong place at the wrong time for just about anywhere in the world, except for Asia. So inevitably we draw the short straw and either early mornings or late at night-type phone calls' (19 13:30); 'normally Australia gets the rough end of the stick' (21 03:19); 'it's always Australia that shifts… it's almost invariably the Australians who get up early or stay up late. The other guys tend to get away with it a bit more' (25 17:00). One subject said that the times of day they would take calls were 'pretty shocking' (18 08:10). Because Australian workers were sometimes in a minority, '[overseas partners] preferred to work within business hours… the multitude wins, and we were not head office, and therefore everybody should work around them. So that's kind of how it went' (21 05:00); 'the greatest proportion of odd hours would be handled by the Australian part of the collaboration, but not exclusively; but the sort of wee hours of the morning is usually something we're more likely to do' (24 05:59). Sometimes an effort was made to accommodate Australian team members, with a meeting originally scheduled for 1 or 2 a.m. moved to 11:30 p.m. local time (08 17:27). However, it appeared to be a more common experience for Australians to have to accommodate their overseas counterparts, with one respondent noting: 'It involves mainly late nights because I tend to work closer with the European team, and it usually involves working late nights on my side. I think I try to make it easier for my colleagues to work with me. There are several priorities within the business, and a lot happens in Europe and in the US; I feel we are the ones mostly located a little bit outside of the loop. I just always try to make it easier for them to work with me, so I try to accommodate my hours within their working hours' (09 01:40). One interview subject had a sense of resignation about being in Australia and working on global projects: 'think you need to recognise that that's just part of the deal: if you work within a multinational structure and you live in Australia, and especially if it's a more US or European-centric organisation, it's going to be what suits the head office more than what suits other countries' (21 04:04).

Because of working odd hours, some interviewees found their social and family life disrupted; one subject reported they were 'attending a meeting at 9 p.m. on Friday night' (08 04:17), and another would take calls in the office at 1 am because they disliked taking calls at home and wanted to have files at hand (17 08:59).

It was generally noted that jet lag was generally worse on return to Australia; flying overseas, 'you have to keep driving yourself' (25 06:45) but on your return, you're 'safely in the bosom of your family' (25, notes). This pattern of jet lag being worse on return to Australia was noted by another interview subject: 'largely speaking, the return trip is leaving people the most exhausted… going there's easier, a lot more fun' (01 16:17). It seems that the traditional model of jet lag ('west for owls, east for fowls' (Waterhouse *et al.* 2007)) does not apply particularly well to business travellers. Most of the research has been conducted in athletes (Lemmer *et al.* 2002; Waterhouse *et al.* 2002), and business travellers appear to adjust differently. For an athlete, physical performance is key. For a business traveller, wakefulness and cognitive function are more important. This apparent lack of effect of direction for business travellers is something that will be explored in further detail in the quantitative survey for this study.

In summary, Australian workers in the biotechnology sector often work in teams that span many time zones, with daylight saving being an occasional, but usually minor, complication. Due to this large time zone disparity, meeting times are often at unsociable hours of the day. About the directionality of time, the rules on chronotype and flight direction don't seem to apply as strongly with these business travellers as has been found with previous research and is investigated further in the qualitative part of the study.

Having discussed the effect of the physical and temporal distance between Australia and partner nations, this analysis now turns to other forms of distance encountered by interview subjects, namely cultural and language distances, to separate their effects from that of temporal distance.

6.3.3 Cultural & language distance

Cultural and language distances are also closely linked (Weber 2015), and this section addresses both forms of distance, first cultural distance, then language distance.

Cultural distance has been well-documented in the literature, and Hofstede's measures of cultural dimensions have received a broad degree of acceptance as a valid measure of this (Hofstede 1984). Generally, interview subjects expressed a strong preference for working with cultures that were more aligned with their own (02 12:24). Cultural differences were cited as a significant factor in performance failure (02 13:00; 07 03:15, 08:00), and cultural sensitivity was noted to be important (05 02:52). Another subject had undertaken cultural awareness training (06 01:15).

Frequently, colleagues from the United Kingdom were regarded similarly to those in Australia, with similar cultural values (25 15:00), although one subject found the English indirect (01 05:00). Directness was particularly noted with Northern European team members: ‘the Danish tend to be quite blunt’ (02 07:19); ‘the Dutch are renowned for being very direct’ (22 19:00); ‘the Dutch, and as a nation they're a very direct nation, that’s been my experience, and small talk wasn’t a lot of what we did’ (18 20:55); ‘the Swiss like to be straight to the point’ (01 14:34), whereas Southern Europeans were noted to be slightly more indirect (22 19:59) and having a more relaxed work ethic (07 06:40; 13 06:03). Generally, however, there was similarity between European and Australian business cultures, with one subject stating that ‘the Europeans and the Australians generally on an even playing field’ (08 09:41).

In Hofstede’s model of cultural values, the United States is similar to Australia (Hofstede 1984), and this similarity was noted by several interviewees: ‘the Americans… and the Australians [are] generally on an even playing field’ (08 09:34), and that Americans would have open discourse (25 15:30). Americans were also noted to be direct (05 03:55): ‘Americans tend to be quite straightforward, like Australians’ (07 07:14); ‘the US is pretty direct’ (02 18:10), and that if Americans disagreed with something they would say so (02 14:45), although not all interview subjects shared this experience, with one subject stating that ‘Americans can sometimes dance around a subject, or want to confer with colleagues before making a decision’ (21 01:31), and their processes often take a lot of signoffs (21 02:14); and another complaining that Americans were ‘not telling you direct to your face what they actually want you to do’ (13 07:42). While Americans generally have a reputation for directness, this was not the universal experience. Lack of directness was also noted with Asian countries (19 11:00), with reference to China (13 07:30; 25 13:45), as well as Japan (‘they’d rather be polite than direct’, 16 09:25), which directly led to project failures in China (07 03:18) and in Japan (02 13:00). India was also cited as a difficult place to work: ‘India’s a very, very strange place… there’s a lot of idiosyncrasies in the way they do things' (08 12:45), and a project failure was reported due to misunderstanding from lack of directness (07 08:59).

Several interview subjects reported difficulty in dealing with Americans with regard to time zones: 'Americans tend to be less understanding of time zone differences, so it always took a bit of time to educate Americans, and they would come to the party with alternating, although I have worked with people who said 'no, you've got to work within our nine-to-five East Coast America' (11 03:39), and similarly, 'the US sometimes has been a bit less flexible in their timing, but it varies depending on who you're working with' (17 05:44). One American company even had a written policy stated that stated 'calls are made within business times for the head office' (11 05:14). Another interview subject said 'the US is very US-centric, so they often don't appreciate that other countries are in different time zones' (17 07:12). This lack of willingness to negotiate on time zone differences contrasts with the experience with Europeans: 'Europeans tended to recognise time zone differences and so we could take it in turns, people working out of office hours' (11 03:22), and 'European companies tend to be more aware of time zone issues; American companies, in general, less' (11 04:35).

Several interview subjects noted difficulty presented by cultural differences and conducting business in Asia, with a greater need for relationship building noted by one interview subject (19 05:50, 08:17). The phrase 'power distance' was used: 'I think in Asia there's a lot more power distance' (21 02:37), and another subject referred to Asian businesses as operating 'like an army' (07 02:50). This increased power distance in Asian nations relates closely to Hofstede's measures of power distance (Hofstede 1984), and Hofstede's model of cultural distance appears to be replicated somewhat in the ease of working with partners internationally.

Language distance is another potential confounding factor in assessing the effect of temporal distance. Most participants reported little or no language barrier (14 03:10; 21 00:46; 22 01:01; 24 04:29; 28 00:57), even with colleagues from non-English speaking countries (02 06:44; 03 04:00; 08 02:44; 18 06:35), and English was the official language as company policy for one respondent (05 04:31).

However, for a few interview subjects language emerged as a barrier in dispersed teams (19 06:44), especially in the Asia-Pacific region (07 07:56; 11 27:43; 15 10:44; 17 02:01, 02:45; 23 08:28). Accents could also be an issue, especially with videoconferening (06 02:01; 25 11:29; 27 03:13).

While language emerged as an issue for several interviewees, it does not appear to have as significant impact on the performance of dispersed innovation teams. Having examined the gap controls, this analysis now turns to the nature and size of dispersed innovation teams.

6.4 Impact-Mitigating Behaviour

6.4.1 Amount of Travel

Because of the geographic dispersion of these innovation teams, large amounts of international travel across multiple time zones were reported by most interview subjects, with typical flight destinations including the United States (02 18:45; 12 18:37;13 18:50), London (02 18:45; 14 11:41; 15 00:45; 16 02:57), Paris (03 09:10), Shanghai (07 18:30; 25 03:59) and Singapore (02 18:45; 15 00:45; 21 07:43). Frequency of travel varied considerably, from 'once a year, maybe' through to six times a year (13 14:00; 18 02:05; 19 02:00; 23 03:22; 24 01:47; 26 01:30). The duration of trips was quite varied as well, with the extremes being a two-day trip to Europe (24 12:59), and a seven-week trip to Europe (13 13:00).

6.4.2 Face-to-Face Contact

The need for travel was underscored by participants agreeing that face-to-face contact was 'absolutely necessary' for travel (25 24:00), and almost all interview subjects said that it was absolutely vital to meet face-to-face (10 20:29; 11 17:47; 12 15:14; 13 27:14; 15 19:29; 18 20:14, 21:30; 19 03:43, 06:02; 20 09:30; 21 09:33, 12:28; 22 04:14; 23 06:29, 06:44; 24 03:30, 04:05; 25 09:05, 24:00, 24:59). This total agreement was one of the most striking findings of the interviews, with comments including 'face-to-face is probably the best form of communication' (11 17:47); 'nothing beats sitting down face-to-face with people to have effective communication' (12 15:14); 'phone is the worst [form of communication], the best is face-to-face' (10 20:29); 'nothing beats a face-to-face, even if we are geographically in the same position, in the same country' (15 19:29); 'it's much better to do the meeting face-to-face, even if it's far away. I have to go down there [the United States], but it's really worth it' (23 06:44); and that face-to-face communication is 'a lot more synchronous' (21 09:33). In promoting their business, one interview subject spoke of the importance of an initial face-to-face meeting: 'I would always do face-to-face on the "first date", and I would always do face-to-face in detailed negotiations on a contract' (25 09:11). Others also spoke of the importance of a face-to-face meeting at the beginning of a project (18 20:14; 21 12:28; 24 03:30). One interview subject gave two reasons for the importance of face-to-face meetings: demonstrating that the meeting is important (having come from the other side of the world), and that 'fundamentally human nature hasn't changed a great deal in this age of virtual communications. People still like to be able to meet, shake hands, learn about the person who they're about to possibly put a tremendous amount of trust in' (22 04:14). Relationship building was a key theme identified by several interview subjects as being a reason for face-to-face contact, despite advantages in communication technology (13 27:14;

20 09:30; 22 06:29; 25 24:59). The benefit of direct contact was also mentioned by one subject in ongoing discussions (19 03:43, 06:02) and misunderstandings were less likely with face-to-face contact according to one interview subject (18 21:30).

This need for face-to-face contact encouraged travel (01 13:15; 23 06:31; 24 04:05), and while communication technology has reduced the need for frequent direct contact, it is still sometimes necessary (02 16:59).

The benefits of face-to-face contact on team building is best summed up by the comments of one interview subject: '[we] get a lot of the team members together in one location, and that always was such a great thing to do because – the energy of the team always – everyone's developed much stronger relationships. You could feel that difference for a period of time afterwards. You feel it's a safe space' (06 04:00).

This strong support for meeting face-to-face aligns with the academic literature that affirms the merits of face-to-face contact, particularly at the initial phases of a project (Kirkman *et al.* 2004; Maznevski & Chudoba 2000). Having noted the value of direct contact, this analysis turns to the flights that make this direct contact possible; specifically, examining whether flying business class confers any benefit.

6.4.3 Business Class Flights

To date, there have been no studies on the effect of flying business class on executive performance. There have been limited studies on the benefits of flying business class on cardiovascular incidents, examining the possible benefit of business class travel in preventing deep vein thrombosis (Jacobson *et al.* 2003), but nothing in terms of alertness or cognitive function.

There appears to be some degree of variation in flight class in this cohort. Several interview subjects reported flying long distances in business class (03 05:44; 06 07:45; 15 01:20; 27 01:44) which helped with sleep (06 07:59; 10 08:01) and getting work done (12 09:14), and one interview subject was adamant that their staff should fly business class: (01 15:15). However, there was no universal consensus for flying in business class, with several interviewees reporting that they flew economy internationally (19 03:29; 20 09:45; 26 03:25; 28 01:55), or a mix of economy and premium economy (14 02:59; 16 03:33; 21 08:28), or premium economy which was company policy for two interviewees (22 03:45; 23 04:02). Cost was a factor for several interview subjects (02 09:29; 15 02:30; 25 05:45), and another interview subject burst into laughter when asked if they flew business class long distance (13 17:15). One interview subject reported that company policy was consistently overruled for their regular annual business conference in the United States, so that they travelled economy instead of business class (09 15:29). Several mixed flight classes, where long distance international flights were business class but shorter domestic flights in Australia or the United States were economy (03 05:44; 11 23:15; 18 06:00).

There does not seem to be any consensus on the merits of flying business class from this cohort, and one interview subject who regularly flew economy to the United Kingdom complained: ‘if it’s really that valuable to get me over, is it worth having me over and in the right frame of mind? In which case, paying that extra four thousand dollars or whatever it is – would that make that difference that means I actually can function there right away’ (15 18:53).

This review now focuses on the various means deployed by workers in this sector to minimise the effects of jet lag.

6.4.4 Jet lag

As previously mentioned, jet lag was noted as a significant issue by most of the interview participants. Most international travel was by plane, although one interview subject reported travelling by train within Europe (03 11:11). Jet lag symptoms were reported by several subjects (06 05:05; 07 12:00; 10 12:30), including an acquired respiratory infection (02 18:27). The adverse health effects of jet lag were compounded by poor diet and lack of exercise: 'all the bad habits come out when you travel… you're eating out the entire time. There's just no other option' (13 10:56).

Arrival times at international destinations such as 6:00 a.m. were based flight schedules (03 05:14), with one subject trying to time flights to be productive (05 02:30). Some interview subjects went to work immediately on landing (03 10:47) and worked through fatigue: 'basically as soon as you touch down wherever you are the next day, you have your work responsibilities to deal with. The body is tired, but you just kind of work through it, that's been my experience. You're running on adrenaline a lot of the time.' (06 04:59). These concepts of 'working through fatigue' and 'running on adrenaline' were recurring themes in the cohort studied, suggesting a culture of using 'focus' or 'pushing through' to overcome jet lag rather than treatments for jet lag based on scientific evidence.

It was apparent that jet lag is a substantial and widespread problem for this population with associated negative effects on performance. The most effective treatments for jet lag have been identified as light therapy, melatonin, and scheduling sleep (Sack 2010). Caffeine lengthens the average duration of the circadian rhythm by approximately 40 minutes (Burke *et al.* 2015), and caffeine can be useful for daytime drowsiness but problematic for insomnia (Sack 2010). There was limited uptake of evidence-based treatments for jet lag (see Table 6).

No subjects reported using timed exposure to light (or intermittent bright light therapy) to treat jet lag, a single subject reported using melatonin (24 12:00), and there was little use of sedatives. Instead, a variety of methods not supported by medical literature were reported, including coffee (14 13:30; 21 08:58); exercise (14 13:25; 26 02:16); napping (14 13:42; 26 02:32), and even shopping (13 21:25). Having a gap between the time of arrival and starting work was suggested by several interview subjects (13 21:10; 19 02:45; 20 10:20; 23 04:31; 26 01:46). There were degrees of being affected by jet lag reported ('some people cope with it better than others' 18 02:28) with one team member being reported as being particularly adversely affected (18 03:00). There was one interview subject who would 'soldier on' (15 07:29), and another interview subject exhorted their colleague 'to just keep pushing through' (13 20:05). Not all subjects were affected by jet lag, with one subject reporting 'very little [jet lag] indeed' on regular flights to and from London (22 03:15).

The power of 'focus' to overcome jet lag was reported by several interview subjects, and this does not appear in the academic literature: 'you're going with a mission: I think when you go with purpose you can suffer from jet lag, you're tired in the afternoons and all the rest of it when you're in the States, but you've got things you've got to keep going with… you know why you're there, you've got stuff to get through, and you plan it in' (13 19:35). This need to focus seems to be driven by the need to perform within a short time frame, with little time to readjust on arrival in a different time zone: 'you really often don't have that much time to readjust on the ground' (18 05:02), although a rebound effect was noted: 'I guess it's kind of like a high, a temporary high you get then somewhat fade and turn off the turbos' (15 08:59); 'I think you kind of store up all that need for sleep and then you end up trying to catch it up when you get back' (25 07:29). This use of 'focus' certainly aligns with the repetition of the phrase 'running on adrenaline' that has been used by several interview subjects.

Several things stood out examining how workers adapted to jet lag. Firstly, workers in a science-based industry are not routinely using treatment options that are supported by scientific evidence, but rather finding their own ways of ameliorating the worst effects of jet lag through trial-and-error. This is in marked contrast with the sporting community which has detailed and specific evidence-based strategies available to maximise performance (Nedelec *et al.* 2018; Samuels 2012; Waterhouse *et al.* 2007). Instead, there was the use of 'focus' to overcome jet lag, with a resultant rebound and exhaustion on return to Australia. There also appears to be a workplace culture of 'pushing through', where workers accept jet lag and exhaustion as part of the working conditions ('this is my role, I've accepted it, and it comes with the territory' 06 07:03), and the repeated phrase 'running on adrenaline' certainly seems to illustrate a work culture that undermines, rather than supports, its workers in terms of jet lag and international travel.

6.4.5 Workplace Flexibility

While time zone disparity has a negative effect in terms of jet lag, there may be some benefits in terms of workplace flexibility, and a high degree of workplace flexibility was reported due to the number of late night and early morning calls (02 10:00; 04, notes; 05 06:29; 08 06:30; 09 02:45; 12 12:15; 14 06:15; 23 11:12; 24 06:25). Time *in lieu* was taken by one interview subject after a lot of travel (16 07:31), and flexibility was particularly appealing to one interview subject (05 08:29). The temporal disparity experienced by these workers appeared to give them an opportunity to engage with work in a flexible time frame, rather than be constrained to the more traditional nine-to-five model of work.

Work / life balance was reported as important to one interview subject's company: 'we have a policy that – in fact, we have a very active policy of work / life balance; so, every month the entire team answers a very short questionnaire on the time bookings for the month, and how they feel about that work / life balance. And the company policy is that there's flexibility about start and finish times, we have a core time that ideally you are in the office or are available. But we are happy for people to work at home, so if the call is at nine o'clock in the evening, we're more than happy that people join on the Skype or whatever from their home… There are still particular individuals in the company who would, I think, quite happily work hundred-hour weeks… so we try to have this sort of safety valve to say "hey, come on, go home, take some time off"' (22 10:10). These thoughts were echoed by another subject who supported his employees fitting their work around their lives and not *vice versa*: 'I adopt a pretty flexible approach to staff: a lot of them are part-time work from home – you know, we let everybody work their life. Their work fits in around their life, not the other way around' (10 22:22). However, another interviewee stated that their ability to have some flexibility in the working hours was dependent on who their manager was (09 03:46), and the availability of flexible working hours varied considerably within their company.

Family life was stated as a concern for several interview subjects (19 14:58; 26 09:58; 25 18:07), and a disturbing comment was made by one subject who said, 'in Australia, we had to sacrifice home life and everything to make that [project] happen' (11 02:29).

This toll on family life from large amounts of international travel was very clear to one interviewee, who decided once he had children he would accept a role with limited travel only (07 14:04), and another interview subject had small children and wanted part-time work but was pushed back into full-time work against her wishes (09 04:44). Another interview subject decided that educating their family was an approach to successfully managing the demands of an international role (24 06:44). Several interview subjects reported late night phone calls eating into their personal life (14 06:59; 16: 08:16), particularly on a Friday night (14 06:58). One subject linked the disruption to their social life to their chronotype: ‘if you're an early morning person and you get some 9 p.m. calls, it messes up your personal and possibly your family life as well’ (18 18:30). Working across time zones can lead to disruptions to family and social life due to the temporal distance experienced by team members.

There were some challenges to workplace flexibility noted by a number of participants, particularly in terms of workload: ‘everyone’s open to that [flexible working hours] if you have a late call you can come in later. In reality, there was always a lot of work to do… I never really went in late at all, you know, you just squeeze it into your life somehow’ (06 05:45); ‘occasionally you get that option [for flexible working hours] but it really depends sometimes, meetings are just scheduled and so there is no flexibility, you just push through. And time *in lieu* and days off or whatever as a result of those things is kind of rare’ (19 14:29). There was a certain resignation noted that long work hours came with the role: ‘it’s just part of the job in that matter’ (17 10:29). This was particularly exacerbated by travelling, with one interview subject stating that flexibility and taking time off was not possible while travelling: ‘not while travelling, just because obviously then you would have lost time, having face-to-face time with colleagues in that area. So, we didn’t, no; we stuck with the fairly standard working day still, despite jet lag’ (16 05:55). International travel adds an extra constraint to workplace flexibility due to the limited time at an international destination, and the cost of getting there.

Also, workplace flexibility often came at a cost of working longer hours. One subject reported ‘I also work extra time so, it’s not such a big deal’ (09 03:16), and another ‘plenty of flexibility… I’d work longer hours, without doubt’ (27 06:58). There was a report of employees working longer despite management support: ‘people, certainly in this product development area, can be very driven individuals for the main part… you're always had to push them into taking that time off sometimes' (18 17:33). One subject found a short term (six month) contract with long hours gruelling: 'week in, week out, month in, month out; it does drag you down. It does drag you down. So, work / life balance was something of a challenge' (27 07:46). This increase in hours was particularly problematic for senior management, who seemed to regard longer working hours as part of a deal for promotion: 'particularly the more senior people are – it's part of the role – everyone sees it, 'this is my role, I've accepted it, and it comes with the territory'' (06 07:00); 'you are talking about management executive role… you don't have any timesheets, I mean you get the work done, so that's it' (07 15:13); 'there is flexibility, I think, more for the lower level staff… if you're part of the executive team or the senior team, then there is a certain level of flexibility; it also depends on the individual decides how to count their time with the company, or they operate: part and parcel of what they do… I think for my other colleagues that are more in the administrative nine-to-five role, I think they have the better work / life balance. So someone myself whom I'm considered as part of the team, I have a level of flexibility in my time, but it also means that I'm very much available on call twenty-four seven to my bosses and for the business' (15 16:16); 'generally most of those teleconferences were in the evening; you just suck it up, it's just part of your home time that gets occupied by work' (21 11:11). Several subjects reported longer working days when travelling, typically spending hours answering emails (13 01:16), and one including socialising as well as emails ('you don't really get to switch off at all', 19 09:13), with one subject's working hours coming to a total of fifteen hours working per day (16 07:13). Longer working hours seemed quite frequent in this sector, particularly for the more senior members of staff, and particularly while travelling internationally.

With reference to the traditional nine-to-five workday, one subject said ‘it doesn’t exist. It genuinely doesn’t exist. That’s to say, I think I’ll start at six [a.m.], I’ll finish at midnight, and I’ll think nothing of leaving at three and go picking my son up. It just doesn’t – it just doesn’t come into the equation, what time it is. And your work and all your family stuff, it all fits in’ (25 19:42), and another, ‘I’m not in some nine-to-five job’ (02 10:13). The temporal distance caused by time zone disparity on multinational teams appears to alter the shape of the working day, moving away from the traditional nine-to-five model, blurring the boundaries of a definite start and finish to the working day.

In terms of workplace flexibility, working across time zones appears to offer an opportunity to work hours that suit workers, especially ones with young children; however, this comes at the cost of extended working hours and intrusions of work into family and social life. This is an area that will be further analysed in the quantitative segment of this study.

6.4.6 Communication

One method to minimise the impact of working across a large number of time zones is to set up stable communication technology, which can reduce the amount of business travel (Julsrud, Denstadli & Hjorthol 2014). Videoconferencing can decrease the need for travel, transforming the landscape of working globally in a very short time frame: ‘modern technology has streamlined working across multiple time zones, almost instantly. Even if I think back twenty years… it would have been more difficult to work across time zones… it would have been extremely expensive, phone calls would have been expensive, conference calling would have been difficult, videoconferencing unheard of, certainly unheard of for the average person, internet was really only in its infancy… in twenty five years the world economy has transformed… the ability to engage and employ people in all sorts of different parts of the world based on their skills and expertise and ability to add value has become possible. So, me, here, sitting here in Melbourne can provide value to people sitting in St Louis in the US, whereas twenty-five years ago that was really not possible' (02 15:29). There were a variety of communication technologies used, with modern technology appearing to have a high uptake rate in this sector. Email was heavily used (06 03:58; 08 03:33; 09 12:15; 12 01:29; 17 04:02; 20 03:50; 21 05:58), as was telephone (09 11:45; 17 03:55; 18 07:30; 21 05:45), these two methods were the mainstays of communication. Voiceover Internet Protocol (VoIP) telephones were sometimes used, depending on the connection (14 04:44), and there was a report of SMS messaging being used (19 12:44). Moving to the more advanced forms of communication technology, teleconferences used frequently (06 01:44; 08 03:14; 12 01:30). Other videoconferencing tools used include BlueJeans (24 08:15), FaceTime (24 08:15; 25 10:15), Google Hangouts (19 12:44), GoToMeeting (10 17:14), iMessages (15 13:32), Lync (14 04:44), Skype (10 17:14; 14 04:44; 15 13:32; 20 04:14; 24 08:15; 25 10:15), VidyoDesktop (25 10:15), WebEx (09 11:45; 10 05:29; 18 07:16; 25 10:29), WhatsApp (15 13:32; 20 04:14; 26 05:00 , and Wiper (26 05:00). One interviewee reported using an internal messenger system (09 11:59) as well as an internal hub (09 12:16), but this appears to be an option only for large companies. Another subject would like to increase the amount of videoconferencing: 'we, as a business, don't do as much video conferencing is probably what we should, but it's more phone-based than anything else at the moment' (14 04:44), while another subject reported a mix of communication platforms: 'most of my communication is either email, phone or Skype… I think seeing people's expressions, being able to lip read and see the body language obviously enhances the quality of the interaction. So, in order: email's the worst, then phone, then Skype, and then real life is best' (10 17:14). This lined up with Pentland (2012). This marked preference for the more visual forms of communication was a common theme, although one subject reported that telephone calls had as good an atmosphere as face-to-face meetings, but the attendance rate for teleconferences was lower: ‘I would say that phone calls would have the same kind of atmosphere as a face-to-face meeting… there’s always a higher chance people are missing calls… attendance at the teleconference is always less than face-to-face meetings, particularly if it’s in the office; you can always go around chasing people up if they’ve forgotten about a meeting, there’s always that option of running around trying to find people. You always have to factor in the possibility of people not ringing in to teleconferences’ (11 15:12).

The disadvantage of not seeing people’s faces in a teleconference was noted by several interviewees: ‘you're not able to see people, even if you're able to see people physically via Skype where you can have an image of what’s happening in that room, I think it’s very hard to moderate a discussion where you might have interruptions all the time, where people all say things and someone else might interject to provide their views’ (15 18:30); and ‘I have to call the group of the people, talking to each other without seeing any video. So, I usually ask them to say who is talking, because sometimes it’s really hard for me to recognise who is talking’ (23 07:29). The hierarchy of communication with face-to-face contact as the most preferred method of contact, and email being the least preferred method of contact was stated by several interview subjects, with one subject stating ‘fax or email [is] definitely the least effective form of communication, so teleconferencing is definitely an improvement over that; and face-to-face is probably the best form of communication. But in Australia, unfortunately, that’s a problem with our time zone’ (11 17:43). There appears to be extremely high uptake of communication technology, with a strong preference for the more visual forms.

The advanced nature of the technology platforms used particularly impressed one subject (27 10:00), and another reported that because of advances in communication technology they no longer needed to travel as frequently and could offer services not possible twenty years earlier (02 15:30). An outstanding example of new technology was electronic files for device parts to be 3-D printed sent from Australia to the United States, so that multiple prototypes could be printed and rapidly shipped within the country (18 14:00). One subject stated that improved and cheaper communication technology was the way of the future: 'we will see globally a lot more of that happening, with the way communication and technology is progressing, and is becoming cheaper and easier to access' (20 12:44). While there was a strong uptake of communication technology, there was still a very strong preference for face-to-face communication by the subjects, so it appears that communication technology, although decreasing the need for international travel, is not likely to remove that need altogether.

6.5 Temporal Organisational Approaches to Working across Time Zones

During the interview process, the importance of corporate support for workers who travel across multiple time zones was evident. In dealing with workers who experienced jet lag three distinct management approaches emerged, which we have labelled '*laissez-faire'*, 'concentrate the pain', and 'set the boundaries'. In the *laissez-faire* approach, staff are left to manage their jet lag to themselves; with the 'concentration of pain' strategy, staff are selected so that some team members fly more, others less; and the last strategy was 'set the boundaries', where limits are imposed on hours worked, and time off *in lieu* is offered to compensate those who frequently travel internationally.

6.5.1 Laissez-faire

The *laissez-faire* approach is defined as one where employers leave their workers to manage their jet lag as best they can, without providing any tools, education, or setting any limits on their workload while travelling. From the interview data, it was clear that most companies appeared to use this *laissez-faire* approach. This approach has severe limitations, in that employees are left to develop their own methods for dealing with jet lag, many of which have been shown to be ineffective.

There are several mechanisms that can be used to mitigate the effects of jet lag, with some being more effective than others. The table below shows the treatments used to treat jet lag and the evidence-based effectiveness for each.

Table 6: Methods used for treating jet lag: individual (from interview data)

Mechanism to minimise jet lag	# interview subjects reported using	Medical evidence for effectiveness	References
Light therapy (including eye shades)	0	Strong	Lahti *et al.* (2007); Sack (2010) Samuels (2012); Waterhouse *et al.* (2007)
Melatonin	1	Strong	Arendt (2009); Arendt *et al.* (1987); Brown *et al.* (2009); Herxheimer and Petrie (2002); Petrie *et al.* (1989); Sack (2010); Samuels (2012); Srinivasan *et al.* (2008); Waterhouse *et al.* (2007)
Timing sleep	5	Strong	Sack (2010); Samuels (2012); Waterhouse *et al.* (2007)
Wakefulness agents	0	Strong	Coste and Lagarde (2009); Sack (2010) Waterhouse *et al.* (2007)
Hypnotic agents	1	Strong	Coste and Lagarde (2009); Sack (2010); Samuels (2012); Waterhouse *et al.* (2007)
Caffeine	2	Limited[1]	Aepli *et al.* (2015); Burke *et al.* (2015)
Exercise	1	Weak	Atkinson *et al.* (2007); van Reeth *et al.* (1994)
Flying business class	2	No data	Cohen, Hanna and Gössling (2018)

1. Potentially useful for westward flight, but detrimental for eastward flight.

The four key therapies for treating jet lag, according to Sack (2010), are light therapy, melatonin, timing or scheduling sleep, and medication. No interview subject in the cohort reported using appropriately timed exposure to light. Only one interview subject reported using melatonin to combat jet lag (24 12:00), which is available only on prescription in Australia. Several interview subjects appropriately timed their sleep to synchronise their circadian rhythm, either by staying awake until the evening (10 11:11; 15 05:20; 24 12:10), or by making sure they have enough rest (10 09:00; 14 13:45). There were no reports of wakefulness agents being used to counteract daytime sleepiness, although there was one mention of a hypnotic agent (zopiclone) being used by one subject (10 11:30).

Caffeine is problematic in the treatment of jet lag, as its use has been shown to lengthen the average duration of the circadian rhythm by approximately 40 minutes (Burke *et al.* 2015). This makes it potentially useful for travellers flying westward where the apparent day is lengthened, but detrimental for those flying eastward where the apparent day is shortened. There was one report of a business traveller using coffee, with its active ingredient caffeine, to stay awake (14 13:30).

The use of exercise to alleviate the symptoms of jet lag is even more problematic, with one review stating that 'in practical terms, the substantial levels of activity needed to obtain phase shifts may not be attainable by the majority of people' (Atkinson *et al.* 2007). One interview subject said 'I just force myself to keep active: so running, going for a walk, get some fresh air, going outside, going for a run, going to the gym, playing golf, whatever that is, I'll just make sure I go as long and as far into the night as I can' (14 14:24).

There are currently no data to indicate that business class has a beneficial effect on jet lag, and the key study on the benefit of flying business class have been investigating possible effects on deep vein thrombosis (Jacobson *et al.* 2003). Two interview subjects reported deliberately flying business class to minimise the impact of jet lag and obtain adequate sleep (06 07:48; 10 08:25).

Examining the strategies that workers use to treat the symptoms of jet lag, some of them appear to be suboptimal, not supported by evidence, and some may even lead to negative outcomes. The negative effects of jet lag on workers who travel internationally can be divided into two main categories: impact on family life and work / life balance, and impact on health outcomes.

Family life disruption was cited by interview subjects as a major issue (24 06:45); one interview subject said that his wife hated his frequent travel (19 15:59), another saying that 'we had to sacrifice home life' to make a project happen (11 02:29), and one subject changed jobs when he began a family (07 14:35).

Regarding health outcomes, diet was negatively impacted by international travel: 'all the bad habits come out when you travel… you're eating out the entire time. There's just no other option' (13 10:55). Fatigue was a significant issue: interview subjects reported pushing through the tiredness while travelling (06 05:10; 17 12:25), experiencing it worse on return to Australia after travelling (01 16:16), and experiencing a delayed onset of jet lag on return (17 11:29). This exhaustion on return to Australia was referred to as 'running on adrenaline' quite frequently: 'it's probably adrenaline that keeps you going in one direction, and as you arrive back and the adrenaline's over because the big meetings are done, then you sort of land at home and maybe take it easy for a day or so' (24 11:35). In a similar vein, another interviewee said 'if you've got long-running days of late nights, having to work late nights, then you don't seem to notice it because you've got things you need to do. But it does kick in once it's all done and dusted, once the adrenaline has dropped off' (17 11:47), and another, ‘you have to keep driving yourself to get up to attend meetings, to – you know, accept the three o'clock in the morning wake up, you start your day at three o'clock in the morning essentially… you're driven largely by adrenaline… I think you kind of store up all that need for sleep and then you end up trying to catch it up when you get back’ (25 06:46). Extreme levels of fatigue were reported by one subject who said, ‘it comes to a point where I was waking up in a hotel and I never knew where I was… sometimes you don’t wake up for a meeting’ (07 12:00). Clearly, fatigue is a key issue for most of this cohort.

Cognitive function was also reported to be impaired by jet lag, with one interview subject finding sustained mental focus a challenge and would ‘ration’ his focus (17 13:33); health challenges were also mentioned by one interview subject, who said that he had picked up a cold from his international travel (02 18:29).

The negative effects of frequent travel has been termed the ‘darker side of hypermobility’ (Cohen & Gössling 2015), where the glamorisation of travel is juxtaposed with the ‘physiological, psychological, emotional and social costs of mobility for individuals and societies’, with an ‘ominous silence’ regarding negative effects of frequent travel. The negative effects that the interview subjects reported were firstly, an impact on family or social life, upsetting the work / life balance; and secondly, physical concerns, mainly fatigue (particularly after returning from travel), but also impaired cognitive function and even a cold. These potentially negative effects can be attributed to the *laissez-faire* approach by management of these business travellers, and the lack of proactive intervention by companies regarding employees who frequently travel for work could potentially breach the company’s legal responsibilities (Black & Jamieson 2007).

6.5.2 'Concentrate the Pain'

As a way of minimising the impact of travel on productivity, some staff members were selected to travel in preference to others, as not all travellers respond the same way to jet lag (Samuels 2012). This could be done in four ways: by function, where staff from certain departments travel more than others; by management level, where there is a particular management level that travels frequently, with more senior staff mostly remaining at company headquarters and more junior staff remaining within their geographic region; by location, where members from one particular country fly more than others, or by combining destinations so that multiple international trips were condensed into one large international trip, minimising the number of overseas trips required.

By allocating travel to certain functions, such as sales (07 09:55; 09 14:15), training (09 14:15), project managers (12 02:40), support engineers (07 10:10) and business development (22 01:48; 25 22:46), this 'concentrated the pain' to these workers, while other functions such as administration (09 14:15) and regulatory affairs (11 02:57) were reported to have less travel associated with their roles. One business development manager was hired specifically to travel: 'we have one BD [business development] guy who's based in the UK whose job is to travel' (25 07:46). It was clear from the interview material that several roles were expected to have significant travel, others less so.

Another method of 'concentrating the pain' of international travel was through selecting a level of management that took on the burden of flying. Typically, these managers would have regionally based staff reporting to them and would report to managers at the international headquarters. Two interview subjects reported a structure where countries in the Asia-Pacific region reported to a staff member in Melbourne (14 11:00) or Singapore (05 01:15), who travelled among the countries in the region as well as globally, and a similar system was reported in the European arm of a company with the travelling member based in Paris (07 10:37). Senior managers were identified as having a higher travel burden compared with more junior staff by four of the interview subjects (14 09:15; 21 06:25; 25 03:06; 27 01:15), with one stating ‘the person who travels most is me. I'm Platinum on Qatar, and Platinum on Qantas, completely independently, and all of it economy class. So, I still [accumulate] 250,000 miles a year, at least ten round-the-world trips’ (25 22:35).

A third method of ‘concentrating the pain’ is selecting workers in a location to travel, usually to a central hub. In this cohort, asking whether Australian workers travelled more than their overseas counterparts, opinion was evenly divided. Eight interview subjects reported that Australians travelled more (02 03:55; 06 11:35; 08 08:05;12 02:50; 18 01:32; 23 03:44; 24 01:29; 26 00:590, with one of the interview subjects stating that she travelled more because she was more remote (23 03:44). However, seven other interview subjects stated that Australian workers tended to travel less than their overseas colleagues (09 17:17; 14 02:05; 15 03:40; 16 01:16; 17 01:00; 19 01:45; 27 01:17). There was one team reported to have locations in Singapore and the United Kingdom as well as Australia, and for this team the Singapore team did the most travelling, being the hub (15 03:40). One of the subjects reported that Australians have a more relaxed attitude, in terms of wanting less travel and more of a work / life balance (09 18:30), while another interview subject complained that ‘one of the issues with Australia we don’t like to travel that much…I think we’re spoilt’ (01 01:29). One possible explanation for this lack of consistency is that, generally for Australians, distance is a key factor when travelling internationally, and that international travel is therefore a greater commitment. Several subjects used the phrase ‘the tyranny of distance’ when interviewed, which will be discussed in detail. Certainly, companies do concentrate the travel burden by location, whether Australia or overseas team members.

The fourth way to ‘concentrate the pain’ of crossing multiple time zones is to combine destinations when travelling, so that multiple destinations were covered by the one trip. This was frequently used by interview subjects travelling from Australia to Europe, where multiple European destinations would be routinely visited on the one journey (03 11:10; 11 10:00). For Australian travellers to Europe, there was the option of also stopping in Asia *en route* that one interview subject reported (13 07:15). More ambitiously, several subjects reported frequently combining Europe and North America, flying around the world (06 09:50; 11 10:29; 22 02:15; 25 04:00), which was very cost-effective (22 02:46). However, not all interview subjects were able to combine their destinations as easily. For one interview subject, destinations were ‘quite delineated’ (13 14:25), and while most people combined destinations, she was unable to do this, so she would ‘just leave them as multiple trips’ (13 15:35). Combining destinations was a useful and cost-effective method of concentrating the pain of jet lag for travelling workers and used extensively when possible.

The management of jet lag described as ‘concentrate the pain’ used several means to concentrate the pain of the effects of jet lag onto a smaller cohort, selecting by location, function, or management level, or by combining multiple overseas destinations for business travellers from Australia.

6.5.3 'Set the Boundaries'

A 'set the boundaries' approach is one where companies limit the impact of working in teams that span multiple time zones, including the impact of jet lag on their staff, through various means such as offering business or premium economy class flights for distances of more than five hours (Bannai & Tamakoshi 2014; Cohen, Hanna & Gössling 2018), giving time off *in lieu* to offset the time taken in travel, or a rest period of three days between business trips (Cohen, Hanna & Gössling 2018), or ensuring that staff members' work / life balance is appropriate. These three methods of minimising the impact of jet lag on staff are discussed below.

Another way of minimising the impact of travel on performance was flying business class. Despite several subjects reporting having taken business class flights or a mix of classes internationally, to date there are no published data indicating that the class of flight has any effect on cognitive function or alertness. There was some significant divergence in interview subjects' experience regarding flying business class. Some subjects flew business class (03 05:44; 15 01:20; 27 01:40); other subjects flew premium economy (23 04:00); for one interview subject premium economy was company policy (22 03:45), and another flew either premium economy or economy (14 02:54), with other interview subjects flying economy class internationally (16 03:33; 19 03:29; 20 09:46; 26 03:29; 28 01:55). Longer international flights (09 15:27; 15 01:30) were typically more likely to be business class than shorter domestic flights (03 05:44; 15 01:40; 18 05:50), either domestically within Australia or within the United States (10 08:44; 18 06:14), with mixes of flight classes reported (15 02:40). The main benefit reported was adequate sleep (06 07:46; 10 08:01; 14 17:55) and the ability to work on the plane (12 08:17). Company policy around travel has been reported as unclear (Wardman *et al.* 2015), and there is pressure to reduce costs when possible (Roby 2014), and often issues around compliance (Holma, Bask & Kauppi 2015). Flight class policy was typically determined by the company (or client for a consultant) (09 15:27; 10 09:31; 15 01:40; 21 08:25), with cost cited as the limiting factor in one instance (15 01:55).

The time worked by employees can also be moderated with a ‘set the boundaries’ approach, offering staff who travelled across multiple time zones time off *in lieu* for time taken to travel, which was accrued by some interview subjects (07 15:30; 16 07:35). However, there was a culture of busyness that prevented taking time off *in lieu* reported by some interview subjects, particularly senior staff (03 10:25; 06 06:15, 07:13; 19: 14:40).

Work / life balance was challenging for many interview subjects, and one interview subject reported a detailed ‘set the boundaries’ strategy, with a questionnaire administered to staff every month tracking their working hours (22 12:47). In a qualitative study of international business travellers, there was little support from the human resources department for these travellers (Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007).

The ‘set the boundaries’ limits the negative effects of travelling across multiple time zones by sending staff on business class flights for long international flights, offering time off *in lieu* for hours spent travelling, and monitoring and limiting the number of working hours per month. These measures clearly come at some cost but can potentially prevent burnout and address the business culture of workaholism that has been encountered in this study.

These three management approaches, *laissez-faire*, ‘concentrate the pain’ and ‘set the boundaries’ are used with staff members who travel internationally across multiple time zones, with varying degrees of efficacy; the *laissez-faire* approach appears to be the least effective of the three. The various organisational strategies can use to offset the jet lag experienced by their employees or workers are outlined in the table below.

Table 7: Methods used for treating jet lag: organisational

Mechanism to minimise jet lag	# interview subjects reported using	Evidence for effectiveness	References
'Concentrate the pain'			
Selecting class of travellers	16	No data	--
People hired to travel	5	No data	--
Combining destinations	6	No data	--
'Set the boundaries'			
Policies for those who travel	8[1]	Strong	Cohen, Hanna and Gössling (2018); Gustafson (2012a, 2014); Mäkelä and Kinnunen (2018); Welch, Welch and Worm (2007); Welch and Worm (2006, p. 298)
Delegation	0	Limited	Welch, Welch and Worm (2007)
Monitoring work hours	3	Strong	Bannai and Tamakoshi (2014); Ganster, Rosen and Fisher (2018); Hewlett and Luce (2006); Mäkelä and Kinnunen (2018); Pfeffer (2018)
Time off *in lieu*	3	Strong	Bannai and Tamakoshi (2014); Ganster, Rosen and Fisher (2018); Hewlett and Luce (2006); Pfeffer (2018)
Flying business class	11	No data	Cohen, Hanna and Gössling (2018)

1. There was a travel policy in place of business class for those who flew more than eight hours, but this was specifically overridden for one interview subject by their company for their national sales conference, which is the only time they travelled internationally.

6.6 Performance Management

6.6.1 Measuring Performance

Having examined the factors in the model of temporal distance, the gap controls that affect performance (physical, cultural and language distance), the size and structure of team, and the various methods employed by Australian biotechnology workers, this analysis now examines the performance of these teams, and how working across large temporal distances affects performance.

The three measures of performance used as dependent variables for the quantitative phase of the study were financial performance, technological performance and physical performance. In the qualitative interview phase of the study, various aspects of the team's performance, the firm's performance and the individual's performance in the context of working in a global innovation team that spans multiple time zones. These three types of performance correlate with financial and technological performance in the case of team and firm performance, and physical performance in the case of individual performance.

The major challenge in quantifying performance was that it is difficult to measure the performance of an innovation team, especially while the innovation is being carried out ('you can only ever score something in hindsight' 01 03:47). Typically key performance indicators were used to measure a project's progress (01 04:01; 02 05:29), similar to the ones proposed by Gittelman (2006), although this was reported to be difficult (01 11:13), so in this study, performance is self-reported by the subjects as per Hall and Bagchi-Sen (2002).

6.6.2 Financial and Technological Performance

Temporal distance had an impact on logistics, which posed a challenge to performance: 'oftentimes there's a misunderstanding about the deadline on their [American colleagues'] part, that they need to get stuff to us a day ahead of what the actual deadline is for them' (02 16:00), and 'there's potential problems with not realising that time zones affect the deadline' (02 16:44). One interview subject reported difficulties with dealing with the United States Patent office because of the temporal distance between Australia and the United States: 'the Patent Office in the US opens at ten [local US time] and shuts at three thirty or something, four o'clock. There's a window, but it's not very convenient at all' (17 08:28), resulting in logistical challenges. However, other interview subjects found they could turn the time zone with Australia difference to their advantage, stating that 'it's usually an advantage that we have another day for filing something, so the deadline's arrived here for submission of a grant in the US, and we still have another twelve or eighteen hours to get it in' (19 15:50); 'usually our time difference, to a degree, plays to our favour rather than against us' (27 08:30).

Communication was also a significant issue for many interview subjects, being isolated not only physically but temporally: 'the other logistics aspect probably just more the time frames of when you can have conversations. That's probably the biggest issue' (18 12:13). However, this also worked as a positive when using a 'follow the sun' methodology ('the clock worked in our favour in some ways', 18 13:00). Temporal distance was therefore both a positive and a negative in terms of logistics and deadlines.

There is a sense of isolation from some interview subjects who experienced the 'tyranny of distance' (Blainey 1966; Gilding 2008), with one interview subject who moved to Australia commenting 'Australia, it's a bit aside from the rest of the world from a geographical standpoint' (07 18:59). The temporal isolation is because the 'time zone difference to Europe and England [from Australia] is huge' (01 01:59), so it is infrequent for team members to be working concurrently.

The temporal and physical isolation of Australian members of global innovation teams had several challenges relating to financial and technological performance. Logistics is a challenge with working hours in the United States or Europe resulting in team members having to work outside of standard business hours. Communication is also a challenge due to the physical and temporal distance within globally dispersed innovation teams. There is also a sense of isolation, particularly with Australian team members, due to not only the physical isolation of Australia from other team members' nations, but also the temporal isolation, where the Australian team members are working in very different time zones to their fellow team members.

The effects of temporal dispersion on the financial and technological performance of globally dispersed innovation teams is studied further in chapter 7. This thesis now turns to the effect of temporal dispersion on the physical performance of team members.

6.6.3 Physical Performance

As described in chapter 3, working across time zones, particularly long-distance travel across multiple time zones can cause impaired physical performance due to jet lag (Sack 2010; Waterhouse *et al.* 2007). The physical symptoms that are often the most problematic to business travellers include fatigue (Coste & Lagarde 2009), impaired cognitive function (Cho 2001), and greater susceptibility to illness (Schwellnus *et al.* 2012).

Fatigue was reported by a number of business travellers with a negative effect on their performance: in the words of one interview subject, 'sometimes you don't wake up for a meeting' (07 12:30). The phrase 'running on adrenaline' was used by several interview subjects (07 12:00; 17 11:47; 24 11:35; 25 06:46), such as one subject who said that when they travelled, they were 'running on adrenaline a lot of the time' 05:30 (06 05:29). On return to Australia, fatigue was particularly challenging: 'it [tiredness] does kick in once it's all done and dusted, once the adrenaline has dropped off. You do tend to notice it. If I've gone for days at a time I find it much harder to shake the tiredness' (17 11:58).

Cognitive function, which is crucial for business travellers (Czeisler & Fryer 2006) can also be impaired by jet lag (Sack 2010). This was reflected in the study cohort, with one interview subject who frequently travelled internationally reporting 'it came to a point where I was waking up in a hotel and I never knew where I was' (07 12:00). Some interview subjects reported using 'focus' when they travelled internationally, but this sense of focus came at a cost: 'when you don't need to focus as much I tend to become very blurry [laughter] for want of a better way of putting it' (17 13:35). Many of the interview subjects reported difficulty with cognitive function when they travelled (06 05:15; 07 12:00; 17 13:35).

Increased incidence of illness has been reported with jet lag (Schwellnus *et al.* 2012), and one interview subject attributed their cold at the time of the interview from recent travel (02 18:29).

One striking finding discussed previously that several interview subjects found the return flights to Australia more difficult than the flight leaving the country. Interview subjects reported 'pushing through' fatigue while travelling (06 05:10; 17 12:25) which was also referred to as 'running on adrenaline' (02 18:16; 06 5:15; 10 11:48; 15 08:31; 17 11:47; 24 11:35; 25 07:14), which results in a rebound effect on return (01 16:16; 10 11:48; 17 11:29; 25 06:46). This is not something that has been described in the jet lag literature, but rather a lesser effect of flying westward versus eastward (Flower, Irvine & Folkard 2003; Lemmer *et* *al.* 2002; Monk *et al.* 2000; Waterhouse *et al.* 2007), and the issue of worse jet lag on return versus the directional asymmetry for jet lag discussed in chapter 3 is examined further in the quantitative phase of the study.

In summary, the factors affecting physical performance in members of global innovation teams are centred around fatigue and cognitive function. Of interest is the finding in this qualitative phase that return flights have a greater negative impact on performance than outbound ones, and this issue is examined further in the quantitative phase of the study.

6.6.4 Summary of Performance

Performance was difficult to quantify by subjects, especially while a project was taking place. There were some challenges with logistics in terms of aligning deadlines, but there were also some unanticipated benefits for Australian biotechnology workers with extra time because of the time zone difference between other countries and Australia. The most significant issues around performance appear to be biological, with jet lag and long working hours affecting alertness and cognitive function reported by several subjects. Finally, the need for cooperation within a team was summed up by one participant: 'it's much easier when all the parties are happy to make a bit of an effort to make it a bit easier for others in other time zones' (17 18:30), enhancing team performance. Because of the challenges reported by the interview subjects in measuring performance, in the quantitative part of the study performance will be self-reported by the subjects.

6.7 Summary

Reflecting on the data provided in the qualitative phase of the study, the key phrases volunteered by the participants are particularly useful in gaining an insight into the characteristics of the cohort. The phrase 'tyranny of distance', referring to a book written just over 50 years ago (Blainey 1966), shows that while Australians have access to rapid flight and communication tools, there is still very much a feeling of having to travel onerously long distances to reach many destinations, typically the United States or Europe (see Figure 9). Another common phrase was ‘running on adrenaline’, demonstrating a sense of exhaustion, particularly on the return leg to Australia; and the phrase ‘pushing through’, indicating that while this exhaustion was keenly felt, it was necessary to overcome it forcefully, resulting in more tiredness on returning to Australia.

The various forms of distance (temporal, physical, cultural and language) are discussed, and the interview cohort reports a sense of isolation by working in Australia. There appears to be a balance, in that working with teams in the United States or Europe has a greater deal of temporal and physical distance, but minimal cultural and language distance; while dealing with team members in Asian nations, the cultural and language distances are prominent, while the temporal and physical distances are greatly reduced. It appears at this stage that there is some slight preference for working with team members in the United States or Europe because of this (see Figure 9), and this is reflected in the team member locations (see Figure 10).

The impact-mitigating factors that workers in globally dispersed teams use to minimise the impact of this dispersion are illuminating. Travel is often conducted with multiple destinations combined to reduce the amount of travel. Interestingly, every single interview participant stated that face-to-face contact was extremely valuable and indispensable to team performance, and therefore necessitating travel from at least one team member. This results in the need for strategies to overcome jet lag, not all of which are effective (see Table 6 and Table 7). The importance of workplace flexibility, particularly in terms of working hours was stated by several interview subjects, and communication strategies to overcome the distances within teams also discussed, with a high uptake of communication technology.

The effect on the performance of these teams caused by the distances within these teams has also been identified: the challenges in measuring the performance of these globally dispersed teams; the challenges of logistics, particularly the challenges of logistics to and from Australia, with the difficulties posed by the time zone differences has been outlined; and the potential effect of working across multiple time zones, particularly the effect of jet lag, on interview subjects' cognitive function has been identified.

The interview cohort, from their own remarks, appears to be isolated and frequently exhausted due to working in globally dispersed teams, and the qualitative data has unearthed issues to explore in the quantitative section of the study.

Having discussed the results from the interview phase of the study with 28 interview subjects, this thesis now turns to the results from the survey phase of the study with 153 survey participants.

7. Survey Results

7.1 Introduction

One of the findings of the interview phase was that there was a managerial component to the management of workers who travel frequently or are part of teams that span multiple time zones, with three different management approaches which have been defined as *laissez-faire*, ‘concentrate the pain’, and ‘set the boundaries’. The *laissez-faire* approach is defined as one where management leaves the team member to their own devices in terms of managing working in a team that spans multiple time zones and / or travelling across multiple time zones. A ‘concentrate the pain’ approach is where only selected team members bear the brunt of the effects of working and / or travelling across multiple time zones. Using a ‘set the boundaries’ approach means that limitations are explicitly set by the company management to mitigate the effects of working and / or travelling across multiple time zones, such as with flexible working hours, limiting working hours or flying workers business class.

This chapter will investigate the relationship between the three management approaches as outlined above in a broader organisational contest and organisational performance.

7.2 Descriptive Statistics

7.2.2 Descriptive Statistics for Independent Variables

Before investigating the relationship between the three management approaches and performance the key descriptive statistics are presented. Table 8 gives an overview of the mean scores and standard deviations of the independent measures used in the online survey with 147 survey respondents as observed in the sample.

Table 8: Descriptive Statistics for Independent Variables

	Mean	Std. Deviation	α	N
Team characteristics				
Stage of development	2.5900	1.03300	-	147
Average team size	17.3530	44.16100	-	147
Team duration	7.8764	57.54056	-	147
Physical distance	3.9886	1.19546	0.65	147
Cultural distance	3.6152	1.11891	0.87	147
Impact-mitigating behaviours				
Medical approach	3.6179	1.06963	0.64	147
Time management	4.3442	0.99461	0.58	147
Tips & Tricks	4.8100	0.80813	0.61	147
Circadian adjustments	3.5410	1.05230	0.74	147
Temporal organisational approach				
Laissez-faire	5.6831	0.91807	0.74	147
'Concentrate the pain'	4.6873	1.27722	0.64	147
'Set the boundaries'	3.7829	1.21861	0.60	147

Particularly noteworthy that the *laissez-faire* variable had a significantly higher rating than that for 'concentrate the pain' or 'set the boundaries', meaning that the management approach of basically not supporting team members was much more prevalent than for limiting travel to a group of employees ('concentrate the pain') or establishing limits to prevent excessive workload and fatigue ('set the boundaries'). Mathematically, this relationship can be described as *laissez-faire* > 'concentrate the pain' > 'set the boundaries'.

The *laissez-faire* approach, in which team members were expected to 'push through' fatigue and jet lag, work longer hours when they travel, and fly and communicate outside working hours has the potential hazard of physically exhausting team members (Czeisler & Fryer 2006; Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007).

By way of contrast, the 'concentrate the pain' approach, in which certain select employees are expected to cover the international travel obligations, was reported less frequently. There appeared to be some delineation of duties according to travel, with the mean slightly above the neutral value of four (on a seven-point Likert scale of 1 – 7). The benefit of this approach is that people respond differently to jet lag, with some travellers not experiencing much jet lag at all and others incapacitated by it (Samuels 2012), and some workers may have family responsibilities or a marked dislike or inability to travel, while others are happy to travel (Ory & Mokhtarian 2005; Unger, Uriely & Fuchs 2016).

The 'set the boundaries' approach, in which companies have policies that deliberately limit the negative impact of being part of innovation teams that span multiple time zones was the least favoured response of the survey participants, with a score below the neutral value of four. The strategies surveyed included delegation while travelling and ensuring that team members do not work too many hours. International business travellers are poorly recognised as a resource (Welch, Welch & Worm 2007), would benefit from supportive human resources practice to manage travelling (Mäkelä & Kinnunen 2018), and are often part of 'a culture of sleepless machismo' (Czeisler & Fryer 2006).

There was a noticeably high value for the 'tips and tricks' measure (well above the neutral value of four), which may reflect to some extent the high value for the *laissez-faire* temporal organisational approach, where employees who travel or work odd hours find their own strategies for managing jet lag and / or social jet lag.

The values for the average team size and the team duration had such large standard deviations compared with the means as to render the mean value completely meaningless. However, average team size was discussed in section 5.10.4 and team duration in section 5.10.5.

Having outlined the descriptive statistics in the survey phase of the study this thesis now examines the relationships between the variables using regression analysis.

7.2.1 Descriptive Statistics for Dependent Variables

The table below gives an overview of the mean scores and standard deviations of the three different measures of performance measured from 147 survey respondents as observed in the sample.

Table 9: Descriptive Statistics for Dependent Variables

	Mean	Std. Deviation	α	N
Financial performance	4.8418	0.79530	0.92	147
Technological performance	5.6372	0.68558	0.81	147
Physical performance	4.2333	1.03853	0.85	147

The measures have a high degree of reliability and describe scores on a seven-point scale (7 = highest performance, 1 = lowest performance). There is some degree of variation in the scores, with technological performance scoring considerably higher than financial performance, and in turn, financial performance scoring considerably higher than physical performance.

As previously discussed in chapter 5, the variables were created from a composite of questions in the survey that were similar or dealt with similar themes. The responses to these questions were then assessed for internal reliability using Cronbach's alpha (Aiken & Groth-Marnat 2006, p. 92; Nunnally & Bernstein 1994, p. 252; O'Shannassy & Leenders 2016). A detailed list of the Cronbach's alpha for each variable is listed in chapter 5.

It is worth noting that the standard deviation for physical performance is considerably larger than for technological and financial performance, indicating a greater range of results in physical performance experienced by the survey respondents. This could possibly indicate that many respondents have managed their jet lag or social jet lag (or have their jet lag managed well for them), while other team members struggle more with the physical challenges of jet lag and / or working odd hours and experiencing social jet lag. Both the lower mean ranking and higher standard deviation for physical performance indicate that the physical aspects of working in a globally dispersed innovation team, rather than financial or technological aspects, pose the greater challenge to team participants.

These three different types of performance will be examined separately in the regression analysis.

7.3 Bivariate Correlations between Variables

Before discussing the relationships between the independent variables and the measures of performance, it would be useful to examine the relationships between the variables. The table below shows the inter-variable correlations between the variables. Given that the measures are all related to model inputs that potentially affect performance (see section 4.5), it would be expected that these measures would be somewhat related.

Table 10: Correlation Table

	Correlations	mean	std dev	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Stage of development	2.59	1.03	1														
2	Average team size	17.35	44.16	-.026	1													
3	Team duration	7.88	57.54	.118	-.006	1												
4	Physical distance	3.99	1.20	-.006	.030	.002	1											
5	Cultural distance	3.62	1.12	-.071	-.101	.026	.195**	1										
6	Medical approach	3.62	1.07	-.041	.119	-.019	.035	.074	1									
7	Time management	4.34	0.99	.041	.108	-.030	.278***	.157*	.307***	1								
8	Tips & Tricks	4.81	0.81	-.073	.055	-.078	.039	-.021	-.042	.202**	1							
9	Circadian adjustments	3.54	1.05	-.161*	.025	.035	.199**	.242**	.194**	.445***	.157*	1						
10	*Laissez-faire*	5.68	0.91	-.073	-.065	.031	-.225**	.029	.172*	.061	.069	-.114	1					
11	'Concentrate the pain'	4.68	1.28	.001	.047	.001	-.048	.052	.186**	.039	.165*	-.037	.547***	1				
12	'Set the boundaries'	3.78	1.22	-.103	.009	.040	.119	.010	-.022	.111	.187**	.242***	-.093	.111	1			
13	Financial performance	4.84	0.80	-.022	.194*	.093	.124	.085	-.215**	.131	.159	.146	.027	-.041	.246***	1		
14	Technological performance	5.64	0.69	.153	.055	-.013	-.100	-.217**	-.096	.040	.356***	.128	.126	.085	.172*	.412***	1	
15	Physical performance	4.23	1.04	-.031	.069	-.018	.180*	.276**	.434***	.364***	.141	.072	.222*	.216*	-.043	.008	-.073	1

** Correlation is significant at the 0.10 level (2-tailed).*

*** Correlation is significant at the 0.05 level (2-tailed).*

**** Correlation is significant at the 0.01 level (2-tailed)*

Looking at the data in the table above, it is worth noting that financial and technological performance are closely related, with a p value less than 0.01. This would be a reasonable expectation: if a product is particularly technologically advanced or functional, it would be anticipated that it would therefore be profitable. However, it is notable that physical performance (i.e., the wellbeing and ability of employees to carry out their work) was not related to either financial or technological performance, implying that a negative correlation on employee wellbeing does not have a corresponding negative correlation in terms of the technological excellence of a product or in terms of its profitability.

This thesis now turns to the various measures of performance as distinct from each other.

7.4 Multiple Regression Results

7.4.1 Introduction to Regression Results

Having looked at the correlations between the variables created, the thesis now turns to the measurement of the three types of performance that were isolated: financial, technological and physical and their relationships to the independent variables. The financial performance is related to such measures as profitability and cost savings, the technological performance refers to the product performance, and the physical performance relates to the employees' ability to perform and their wellbeing, whether they travelled (and experienced jet lag) or were based in Australia but worked long and / or odd hours to cater for team members in different time zones. The regression results presented in Tables 11 – 13 incorporate multivariate analysis, as opposed to the bivariate analysis in Table 10.

These measures of performance and the variables that were significant in the regression are detailed below.

7.4.2 Drivers of Financial Performance

The financial performance is derived from conventional measures of performance and measures of financial performance were derived from Richard *et al.* (2009). The components were identified in question 11 of the online survey (in full in Appendix C), which were the product meeting sales volume goals, hitting and exceeding its revenue targets, profitability, meeting market share goals (including one-year market share goal), sales volume goal and break-even point. The variables and the correlations are listed in the table below.

Table 11: Regression results part 1: Financial Performance

	B	t	Sig.	VIF
(Constant)	3.164***	4.586	0.000	
Team characteristics				
Stage of development	0.015	0.239	0.811	1.087
Average team size	0.004***	2.893	0.004	1.055
Team duration	0.001	0.976	0.331	1.035
Physical distance	0.056	1.003	0.318	1.186
Cultural distance	0.058	1.009	0.315	1.115
Impact-mitigating behaviours				
Medical approach	-0.202***	-3.225	0.002	1.199
Time management	0.059	0.782	0.435	1.507
Tips & Tricks	0.081	1.006	0.316	1.131
Circadian adjustments	0.055	0.781	0.436	1.441
Temporal organisational approach				
Laissez-faire	0.164*	1.913	0.058	1.646
'Concentrate the pain'	-0.086	-1.428	0.156	1.569
'Set the boundaries'	0.129**	2.403	0.018	1.148
R^2		0.206		
Adjusted R^2		0.135		
F		2.897***		
Df		146		

** Correlation is significant at the 0.10 level (2-tailed)*

*** Correlation is significant at the 0.05 level (2-tailed)*

**** Correlation is significant at the 0.01 level (2-tailed)*

There was a high level of significance with the variable 'medical approach' and financial performance ($p < 0.01$), which related to survey participants' use of prescription drugs (including melatonin, which is only available by prescription in Australia) as well as complaints about frequent travel. While no clear link was found between physical performance and financial performance, it did seem that the use of medication to alleviate the symptoms of jet lag had a positive impact on the financial performance of a project, implying that when employees managed their own health issues regarding jet lag or to working long hours, productivity and was positively associated with profitability.

Financial performance also showed a significant positive correlation with profitability ($p < 0.01$), with larger teams having a positive effect. Whether the larger team size caused the profitability, or whether potentially more profitable projects were allocated more resources in terms of employee numbers is not clear from the data.

To a lesser extent the 'set the boundaries' approach, where management proactively limits the impact of jet lag or travel on staff had a significant positive correlation with profitability ($p < 0.05$). This implies that if management deliberately and proactively manage their staff who travel frequently or who work odd hours there is an increase in the profitability, although an increase in profitability may imply that staff are more readily catered for.

To a limited extent the *laissez-faire* management approach, where management leave employees to manage their health and jet lag as best they can had a slight degree of significance ($p < 0.10$), although whether this means that the money saved from looking after employees who work late or odd hours is turned into profitability, or whether a *laissez-faire* approach actually has a positive impact on financial performance, in contradiction to the stronger association of financial performance and a ‘set the boundaries’ management approach.

Dynamics within the team such as physical or cultural distance, the stage of development or the team duration had no significant impact on financial performance. Some modifications that team members make, such as flying in early, using light therapy, diet, exercise, or adjusting their sleep schedule, did not have a significant impact on the financial performance of team. Neither did a ‘concentrate the pain’ management strategy, where the travel burden is allocated to a specific group of travellers, whether by geographical location or by level of management or job description.

To sum up, the factors that were shown to be significant in affecting financial performance were ‘medical approach’, with team members using prescription medication (including melatonin) to enhance performance; the average team size; a ‘set the boundaries’ management approach, in which the impact of jet lag and / or working long or odd hours is proactively minimised; and to a limited extent a *laissez-faire* management approach. The factors affecting the technological performance of the product(s) that teams were working on is now examined.

7.4.3 Drivers of Technological Performance

The technological performance is derived from conventional measures of product performance, derived from Richard *et al.* (2009). The components were identified in question 11 of the online survey (in full in Appendix C), which were the functionality of the product(s), performing to specifications, meeting quality guidelines and overall success. The variables and the correlations are listed in the table below.

Table 12: Regression results part 2: Technological Performance

	B	t	Sig.	VIF
(Constant)	0.000	6.502	0.000	
Team characteristics				
Stage of development	0.129**	2.479	0.014	1.087
Average team size	0.001	0.822	0.413	1.055
Team duration	0.000	-0.370	0.712	1.035
Physical distance	-0.036	-0.768	0.444	1.186
Cultural distance	-0.127***	-2.601	0.010	1.115
Impact-mitigating behaviours				
Medical approach	-0.064	-1.210	0.228	1.199
Time management	-0.044	-0.690	0.491	1.507
Tips & Tricks	0.241***	3.546	0.001	1.131
Circadian adjustments	0.131**	2.220	0.028	1.441
Temporal organisational approach				
Laissez-faire	0.139*	1.924	0.056	1.646
'Concentrate the pain'	-0.028	-0.552	0.582	1.569
'Set the boundaries'	0.063	1.394	0.166	1.148
R^2		0.237		
Adjusted R^2		0.169		
F		3.466***		
Df		146		

** Correlation is significant at the 0.10 level (2-tailed)*

*** Correlation is significant at the 0.05 level (2-tailed)*

**** Correlation is significant at the 0.01 level (2-tailed)*

There was a significant ($p < 0.05$) correlation between the variable 'stage of development' and technological performance. This is reasonable to expect, as products that are at a later stage of development are more likely to be technologically successful.

There was a high level of significance of the correlation with the variable 'cultural distance' and technological performance ($p < 0.01$), indicating that cultural differences within teams pose a challenge to the development of new products. This mirrors the experience of several interview subjects, one who stated that a project (in India) failed due to cultural misunderstandings (07 08:59).

The variable 'tips & tricks', where team members alleviated their jet lag with sunlight, diet, exercise or rehydration, also showed a high level of significance ($p < 0.01$) of the correlation with technological performance. This implies that team members who manage their jet lag well are developing better products and given that technological performance is strongly correlated with financial performance (see section 7.4), this may indicate that managing jet lag does have some financial benefits to a company, as well as for its technology. Similarly, the variable 'circadian adjustments', in which team members use light therapy or adjust their schedule before they travel showed a significant ($p < 0.05$) correlation with technological performance.

The variable '*laissez-faire*' has some degree of significance ($p < 0.10$) with technological performance. In the light of the higher level of significance of team members managing their jet lag with the recommended treatments of sunlight / light therapy, diet, exercise, rehydration or adjusting the daily schedule do so because of a lack of managerial support, but otherwise the meaning of this is unclear.

The technological performance of a new product(s) that innovation teams were developing were strongly linked to team members managing their jet lag with medically proven treatments (the variables 'tips & tricks' and 'circadian adjustments'). Cultural distance had a negative effect on technological performance, underscoring the difficulties of working in teams across cultures. Finally, there was some degree of significance of a *laissez-faire* management approach and technological performance, possibly due to team members finding and using effective treatments for jet lag without management support. The factors affecting the physical performance of the team members are now examined.

7.4.4 Drivers of Physical Performance

The measures of physical performance of team members (with particular reference to jet lag) were derived from the medical literature. The components of these measures were included in question 10 of the online survey (see Appendix C), which were related to cognitive function and clarity of thought, memory, mood impairment, drowsiness, and light-headedness or dizziness (Becker, Penzel & Fietze 2015b; Czeisler & Fryer 2006; Herxheimer & Petrie 2002; Sack 2010; Spitzer *et al.* 1999; Waterhouse *et al.* 2007). The variables and the correlations are listed in the table below.

Table 13: Regression results part 3: Physical Performance

	B	t	Sig.	VIF
(Constant)	0.038	0.046	0.963	
Team characteristics				
Stage of development	-0.025	-0.345	0.731	1.087
Average team size	0	0.289	0.773	1.055
Team duration	0	0.108	0.914	1.035
Physical distance	0.100	1.529	0.129	1.186
Cultural distance	0.210***	3.086	0.002	1.115
Impact-mitigating behaviours				
Medical approach	0.336***	4.564	0.000	1.199
Time management	0.245***	2.754	0.007	1.507
Tips & Tricks	0.163*	1.723	0.087	1.131
Circadian adjustments	-0.168**	-2.041	0.043	1.441
Temporal organisational approach				
Laissez-faire	0.102	1.014	0.312	1.646
'Concentrate the pain'	0.048	0.679	0.499	1.569
'Set the boundaries'	-0.049	-0.770	0.443	1.148
R^2			0.355	
Adjusted R^2			0.298	
F			6.159***	
Df			146	

** Correlation is significant at the 0.10 level (2-tailed)*

*** Correlation is significant at the 0.05 level (2-tailed)*

**** Correlation is significant at the 0.01 level (2-tailed)*

There was a very high level of significance ($p < 0.01$) of the correlation of the variable 'medical approach' in which team members took prescribed medication (including melatonin) and complained about their travel burden with physical performance, indicating that team members who proactively managed their jet lag performed better. In a similar vein, the 'time management' variable, in which team members flew in early, went shopping or had difficulty attending morning meetings similarly had a high level of significance ($p < 0.01$) with physical performance. The 'circadian adjustments' variable, in which team members used light therapy or altered their daily schedule before leaving for an overseas trip across multiple time zones had a significant degree of correlation ($p < 0.05$) with physical performance, and the 'tips & tricks' variable, in which team members use sunlight, diet, exercise or rehydration to alleviate their jet lag had some significant correlation ($p < 0.10$) with physical performance. Taken together, all these variables measure the survey participants' engagement with strategies for managing their jet lag and the positive impact on physical performance.

Cultural distance also had a very high level of significance ($p < 0.01$) with physical performance, and the reason for this is not apparent.

In summary, team members who were proactively managing their jet lag through scientifically proven methods experienced improved physical performance, indicating that a systematic application of evidence-based methods for jet lag management could benefit employees.

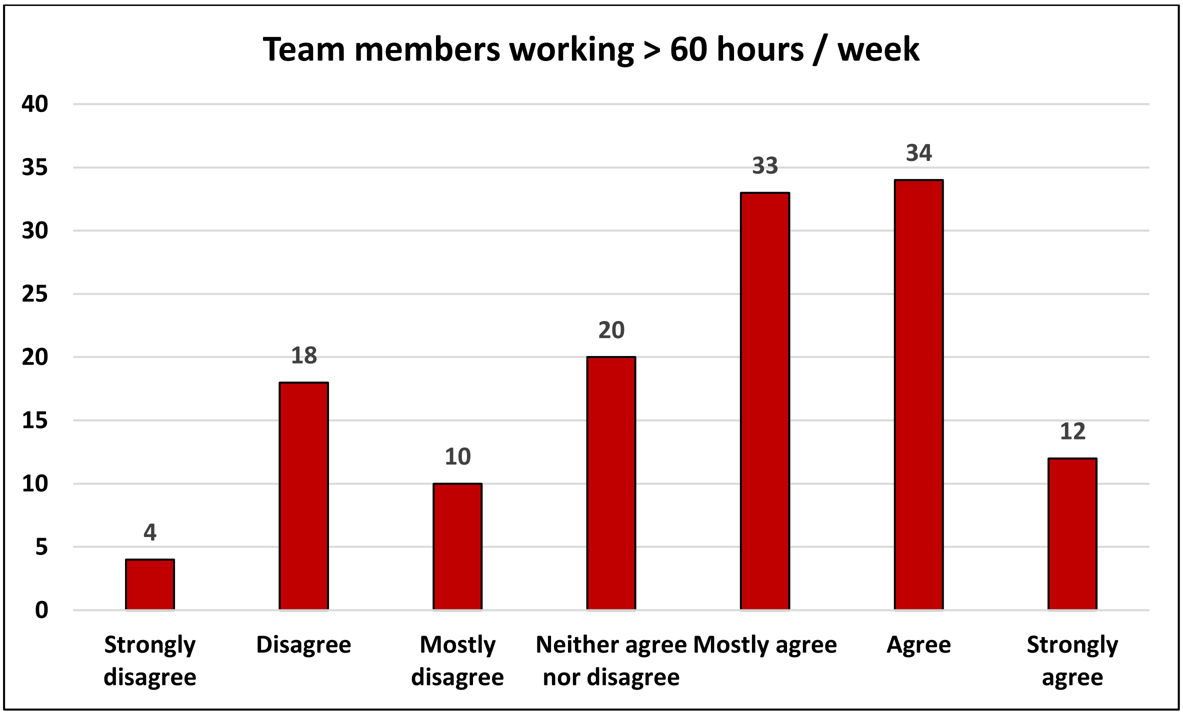
7.5 Long Hours Worked

One of the causes of exhaustion that was reported in the interview phase of the study was team members working long hours (see section 6.4.5), often because of working outside normal hours (Nurmi 2011).

Long working hours has been defined as working more than 61 hours per week (Brett & Stroh 2003). As discussed in section 3.4.2, the effect of working long hours can have severely negative impacts on health (Bannai & Tamakoshi 2014; Ganster, Rosen & Fisher 2018; Goh, Pfeffer & Zenios 2015; Pfeffer 2018).

Question 5.5 of the survey asked participants if team members worked more than 60 hours per week, and the results of this question are given in the chart below.

Figure 15: Team members working > 60 hours / week



There is a definite skewing towards working 60 or more hours in this cohort, with most survey participants agreeing that team members in globally dispersed innovation teams work these very long hours. This finding mirrors the experience of one interview subject who reported that there was a lack of work / life balance which 'does drag you down' (27 07:46).

Another key cause of exhaustion is jet lag, and the management of jet lag by this cohort is now analysed in detail.

7.6 Poor Management of Jet Lag at Individual Level

One of the key issues for people who work in globally dispersed innovation teams was jet lag. Question 10 in the survey addressed the symptoms of jet lag and the severity experienced by this cohort, which is listed in the table below.

Table 14: Jet Lag Symptoms Experienced by Survey Participants

Symptom	Question	Average Usage Score (1 = never experienced, 7 = always experienced)
Exhaustion	10.1 Team members are often exhausted when they travel	5.18
Insomnia	10.2 Team members experience insomnia during and after they travel	4.94
Daytime sleepiness	10.3 Team members often experience daytime sleepiness when they travel	5.31
Mood impairment	10.4 Team members experience impaired mood when they travel	4.47
Unclear thinking	10.5 Team members are unable to think clearly for a day or two after travel	4.33
Memory difficulties	10.6 Team members have trouble with memory when they travel	4.04
Dizziness	10.7 Team members experience light-headedness or dizziness when they travel	3.90
Daytime drowsiness	10.8 Team members are drowsy during the day when travelling for business	4.47
Difficulty concentrating	10.9 Team members have trouble concentrating or thinking clearly when they travel	4.19

Most symptoms were commonly experienced, with exhaustion and daytime sleepiness being prevalent. The symptoms of jet lag described by Sack (2010) being fatigue, daytime sleepiness, insomnia and cognitive function deficits are certainly experienced by this cohort, pointing to a potential role for organisations to fulfil in supporting their travelling staff.

There are many ways that jet lag can be ameliorated, which is discussed in detail in section 3. Several questions in the survey specifically addressed the issue of jet lag and how it was managed by this group of people. Given that this is a scientifically literate cohort working in the development of products in biotechnology, it would be reasonable to expect that jet lag would be managed by this cohort in a scientific manner.

The numbers are taken from the survey questions, where 1 is 'not used at all' and 7 is 'always used' the neutral median score is 4 using a Likert scale. For the full written version of the survey questions, refer to Appendix C. The various methods of addressing jet lag, and the average usage score from the survey participants are listed in the table below.

Table 15: Methods used for treating jet lag: individual (from survey data)

Mechanism to minimise jet lag	**Related question**	**Average Usage Score (1 = never used, 7 = always used)**	**Medical evidence for effectiveness**	**References**
Light therapy (including eye shades)	7.5 Sunlight	4.68	Strong	Lahti *et al.* (2007); Sack (2010) Samuels (2012); Waterhouse *et al.* (2007)
	7.6 Light therapy	3.02		
	7.20 Daylight	4.79		
Melatonin	7.08 Melatonin	3.70	Strong	Arendt (2009); Arendt *et al.* (1987); Brown *et al.* (2009); Herxheimer and Petrie (2002); Petrie *et al.* (1989); Sack (2010); Samuels (2012); Srinivasan *et al.* (2008); Waterhouse *et al.* (2007)
Timing sleep	7.11 Wait until the evening	5.30	Strong	Sack (2010); Samuels (2012); Waterhouse *et al.* (2007)
	7.14 Adjust time	3.95		
	7.16 Adjust schedule	3.76		
	7.22 Adjust daily pattern	3.41		
Wakefulness agents	7.4 Use wakefulness agents	3.35	Strong	Coste and Lagarde (2009); Sack (2010) Waterhouse *et al.* (2007)

Mechanism to minimise jet lag	Related question	Average Usage Score (1 = never used, 7 = always used)	Medical evidence for effectiveness	References
Hypnotic agents	7.7 Use medication	3.46	Strong	Coste and Lagarde (2009); Sack (2010); Samuels (2012); Waterhouse *et al.* (2007)
Caffeine	7.1 Use caffeine	5.51	Limited[1]	Aepli *et al.* (2015); Burke *et al.* (2015)
	7.2 Avoid caffeine	2.97		
Exercise	7.9 Exercise	4.77	Weak	Atkinson *et al.* (2007); van Reeth *et al.* (1994)
Flying business class	6.1 Business class for executives	3.85	No data	Cohen, Hanna and Gössling (2018)
	6.2 Business class internationally	3.08		
	6.3 Business class domestically	1.88		
	6.4 Frequent flyer programs	5.76		

1. Potentially useful for westward flight, but detrimental for eastward flight.

Taking the therapies individually, there is some use of light therapy, but not particularly high. There was reasonable use of sunlight or daylight to stay awake, but little use of light therapy with devices, which have been shown to be effective with jet lag (Lau, Lovato & Lack 2018; Lovato & Lack 2015; Rosa *et al.* 2018). As light therapy is a first-line treatment for jet lag (Sack 2010; Samuels 2012), there is certainly room to improve the uptake of these devices in this cohort, perhaps even at an organisational level.

Melatonin is also a first-line therapy for the alleviation of jet lag (Arendt 2009; Sack 2010; Waterhouse *et al.* 2007). There was very limited use of melatonin in this cohort, which may reflect that melatonin is only available over the counter in Australia (Therapeutic Goods Administration 2017), but more readily available in the United States and Canada.

Scheduling sleep to align with the new time zone is another recognised treatment for jet lag (Sack 2010; Samuels 2012; Waterhouse *et al.* 2007). There was limited uptake of this strategy, although most survey participants were willing to stay up until the evening rather than taking naps, which sounds like the drive to 'push through' previously described by the interview subjects.

Wakefulness agents such as modafinil (Coste & Lagarde 2009) and hypnotic agents such as temazepam (Reilly, Atkinson & Budgett 2001) are also recognised treatments for jet lag, but do not appear to have a particularly high uptake in this cohort.

The use of caffeine, despite being frequently used by business travellers, is not a recognised treatment for jet lag and can be problematic. While caffeine can be used to promote wakefulness (Hansen *et al.* 2018), it can moderate the circadian rhythm by extending it (Burke *et al.* 2015), making it potentially useful for westbound flights, but an additional challenge for eastbound ones. Given that eastbound flying is typically a greater challenge in terms of jet lag for most people (Diekman & Bose 2017; Waterhouse *et al.* 2007), the addition of caffeine extending the circadian rhythm is likely to worsen the symptoms of jet lag rather than resolve them. There was also a low incidence of avoiding caffeine, echoing the business culture of 'conducting business in a cloud of caffeinated jet lag' (Czeisler & Fryer 2006), while the use of caffeine is often problematic.

Exercise was commonly used by this group of business travellers, even though the benefit of exercise on ameliorating the symptoms of jet lag is very limited (Atkinson *et al.* 2007). This finding appears to support the finding that most business travellers in this cohort have little real understanding of the effective treatments for jet lag but are instead encouraged to 'push through' their jet lag, in this case using a rather ineffective therapy.

Flying business class was not particularly common in this cohort. Domestically, there was almost no business class travel, which is likely to reflect the relatively short distances between most major Australian cities. The low use of business class internationally may reflect the long distances between Australia and most of its international partners in this industry, with the 'tyranny of distance' being prominent (Gilding 2008). Executives were not particularly favoured with the use business class. However, there was a very high uptake of frequent flyer programs, with business travellers potentially using the points for an upgrade for some long-distance flights, which was reported by several interview subjects in the qualitative phase of this study (03 05:44; 11 23:15; 18 06:00). There has been almost no research investigating the benefit of flying business or first class on the amelioration of the symptoms of jet lag, with a single study showing flying business or first class had no effect on preventing deep vein thrombosis (Jacobson *et al.* 2003).

Jet lag appeared to be poorly managed in this cohort, and instead of using scientifically validated methods for alleviating the symptoms of jet lag, the workplace culture appears to override this need, demanding its workers ‘push through’ or ‘soldier on’. There appeared to be little recognition of the needs of business travellers. In the words of one frequent business traveller, ‘I just think companies need to recognize that international travel, constantly, is not a benefit but a major hardship’ (Cohen, Hanna & Gössling 2018). While business travellers have been recognised as a ‘neglected but strategic human resource’ (Welch, Welch & Worm 2007), this does not appear to have translated into practice in the area of human resources for international business travellers.

One of the striking observations in the interview phase of the study was that many subjects reported experiencing more jet lag on return to Australia rather than the jet lag being related to the direction of travel. This observation is now explored in more depth, using the data from the survey phase of the study to explore aspects of organisational culture in relation to international business travellers in globally dispersed innovation teams.

7.7 East / West Flights *versus* Departure and Return

An unexpected finding from the interview phase of the study was the number of interview subjects who typically experienced much worse jet lag on return to Australia than they did while travelling (see section 6.4.4). The effect of ‘running on adrenaline’ or using the power of ‘focus’ while travelling has not been reported in the literature.

However, directional asymmetry has been reported with jet lag, where flying eastward typically causes worse jet lag symptoms than flying westward (Diekman & Bose 2017; Facer-Childs & Brandstaetter 2015; Flower, Irvine & Folkard 2003; Lemmer *et al.* 2002; Monk *et al.* 2000; Waterhouse *et al.* 2007). Several survey questions (7.25, 7.26 and 7.27) were created to investigate whether the directional aspect of jet lag is stronger, or if there were more jet lag symptoms on the return flight to Australia. The results are in the table below.

Table 16: Jet lag: east / west *versus* departure / return

Mechanism to minimise jet lag	**Related question**	**Average Usage Score (1 = never used, 7 = always used)**	**Medical evidence for effectiveness**	**References**
Flying west has less impact than flying east	7.27 Team members prefer flying west than east	4.58	Strong	Diekman and Bose (2017); Facer-Childs and Brandstaetter (2015); Flower, Irvine and Folkard (2003); Lemmer *et al.* (2002); Monk *et al.* (2000); Waterhouse *et al.* (2007)
Jet lag can be 'postponed' until return	7.25 Team members can fend off jet lag until they return	4.06	No data	No references
Jet lag is worse on return	7.26 Jet lag is worse for team members when they return home	5.09	No data	No references

Overall there was some directional component to jet lag noted, which wasn't apparent from the interview data, with a definite overall preference for westward over eastward flight. This observation aligns with the literature regarding jet lag.

In terms of fending off jet lag until the return flight, the survey data did not show that this was the case with this cohort, with the score very close to the neutral level of 4. However, there was a high incidence of jet lag being worse on return to Australia, which certainly aligns with the reports of staff 'running on adrenaline' in the interview data. It appears that these business travellers are 'conducting business in a cloud of caffeinated jet lag' (Czeisler & Fryer 2006), which has an impact on their symptoms on their return to Australia.

In summary, while there was some directional component noted by the cohort with a preference for westward over eastward flights, the stronger effect on jet lag symptoms was experienced by the survey participants on return to Australia regardless of the direction of travel. This suggests a place for organisational input into the wellbeing of team members who frequently travel across multiple time zones, and this organisational input is now analysed.

7.8 Lack of Organisational Input

In the interview phase of the study there was limited organisational input into the management of team members who work in global innovation teams that span multiple time zones, although a couple of interview subjects did report a strongly supportive organisational culture for their staff (see sections 6.5.2 and 6.5.3). Questions about organisational input can be divided into the three management approaches outlined earlier: *laissez-faire*, 'concentrate the pain', and 'set the boundaries'. The results of the survey are listed in the table below.

Table 17: Organisational interventions

Intervention	Question	Average Usage Score (1 = never used, 7 = always used)
Laissez-faire	5.2 Team members are expected to ‘push through’ fatigue and jet lag	5.18
	5.4 Team members work longer hours when they travel	5.78
	5.5 Team members work more than 60 hours per week	4.60
	5.7 Team members often fly outside working hours	6.02
	5.8 Team members often Skype outside working hours	5.69
‘Concentrate the pain’	5.9 There is a select group of team members who travel a lot across time zones	5.36
	5.10 In my team, Australians are more prone to fly overseas than other nationalities	4.87
	5.11 Some people in my team are specifically hired to undertake a lot of travel	3.83
	5.13 There are members of my team that cover the travel burden	3.90
‘Set the boundaries’	5.1 There is someone who covers a team member’s work when they travel	3.97
	5.3 There are processes in place to ensure team members do not work too many hours	3.58
	5.6 Team members are flexible with their working hours	5.98
	5.12 In my team, there is an employer policy that caps flying days for specific members	2.33

With the *laissez-faire* approach, organisations do not intervene strongly in the management of staff who work in globally dispersed team or who travel, and these team members are often expected to 'push through' their exhaustion. There were high scores for this 'pushing through', as well as working longer hours when they travel, on top of working long hours and odd hours also. As previously discussed, despite long hours of more than 60 hours a week is known to be hazardous to health, this amount of work is commonly encountered in this cohort (Brett & Stroh 2003). There was a lot of travel and teleconferences outside business hours reported in the study, blurring the lines of a defined working day and having a negative impact on work / life balance. The *laissez-faire* approach showed the highest overall scores in this cohort, showing a general lack of organisational interventions to support staff who work in global teams, particularly staff who travel frequently.

Using the 'concentrate the pain' strategy the burden of working across multiple time zones, particularly international travel, is delegated to a select number of employees. It is known that some individuals experience less jet lag because of genetic factors (Arendt 2009; Ruscitto & Ellis 2007; Waterhouse *et al.* 2007), so it would seem logical to select staff to travel who suffer from minimal jet lag. However, while the results showed that groups of staff who travelled did suffer from jet lag, this did not appear to have been taken into consideration for hiring or as a job description. There was the tendency for Australians to travel more than their colleagues, perhaps reflecting the geographical isolation of Australia from its business partners in this sector.

Finally, the 'set the boundaries' approach has a high level of organisational input, with companies monitoring their employees' wellbeing, particularly staff who travel, and cap their working hours. There was a high score for flexibility, allowing staff to select their own hours to suit themselves and mitigate the effects of having teleconferences at odd hours or travel. However, other scores in this area were very low for items such as delegation and ensuring work hours, and in terms of employers having a policy for capping flight days, this was an extremely low score of 2.33. These scores indicate that apart from allowing a degree of flexibility in the hours worked, organisations did not set boundaries for their staff in terms of working hours or flying time, which echoes the data from the interview phase ('this is my role, I've accepted it, and it comes with the territory' 06 07:03), and organisational culture that did not support their employees' wellbeing.

In summary, the data regarding organisational input for members of globally dispersed innovation teams showed very little input to support team members. These findings mirror those of Black and Jamieson (2007), who, in a series of 25 interview with business travellers who travelled frequently, 'saw no examples of management intervening to help workers restore their work–life balance, even in instances where workers made up to 26 international trips per year'. These findings also reflect Baker and Ciuk (2015), who, in a study of ten international business travellers, found that none of the participants were aware of any formalised support mechanism for staff who travelled internationally frequently. While there was strong evidence of staff in global teams being allowed to select their own working hours, there was otherwise generally very little organisational input to support these workers.

The findings from the quantitative survey phase of the study is now summarised.

7.9 Summary

To summarise the results, it is first worth noting that financial performance and technical performance were strongly correlated with each other, as would be expected; a product that was a technological breakthrough in its field was more likely to be profitable. Therefore, it is likely that there will be some overlap in the variables that affect these outputs.

Financial performance correlated strongly with a ‘set the boundaries approach’, where jet lag or working long or odd hours is proactively managed by the company. This indicates that there is some monetary motivation for companies to look after their staff who work in teams that span multiple time zones. The variable ‘medical approach’, in which team members use prescription medication (including melatonin), also strongly correlated with financial performance, minimising the impact of travelling across time zones and the resultant jet lag.

Similarly, technological performance correlated with similar variables (‘tips & tricks’ and ‘circadian adjustments’), which also related to team members using medically proven treatments to manage their jet lag. Cultural distance correlated negatively with technological performance, highlighting the challenges of working in cross-cultural globally dispersed innovation teams.

However, the fact that physical performance did not correlate with either financial or technological performance may indicate that companies have little motivation to support their staff who frequently travel, although it was previously noted that a ‘set the boundaries’ approach, in which the impact of jet lag is proactively managed by the company, correlates strongly with financial performance. The key finding of the survey data is that the proactive management of these employees (the ‘set the boundaries’ approach) combined with scientifically proven therapies for jet lag enhanced performance significantly.

There was strong evidence of long hours being frequently worked by this cohort, with a high incidence of 60 or more hours a week, defined as extreme work hours (Brett & Stroh 2003). This is despite strong evidence of major health issues associated with overly long working hours (Pfeffer 2018), including an increase in the mortality rate of almost 20% (Goh *et al.* 2015).

Individuals who frequently travel internationally appear to have poor management of their jet lag, with low uptake of clinically proven methods such as light therapy (Lahti *et al.* 2007) or melatonin (Arendt 2009; Herxheimer & Petrie 2002), and high uptake of ineffective or problematic methods such as caffeine (Burke *et al.* 2015) or exercise (Atkinson *et al.* 2007). Instead, there appeared to be the cultural demand to 'push through' or 'soldier on' in the workplace, and 'companies need to recognize that international travel, constantly, is not a benefit but a major hardship' (Cohen, Hanna & Gössling 2018).

There is strong evidence in the literature that jet lag is generally worse flying east than it is flying west (Diekman & Bose 2017; Facer-Childs & Brandstaetter 2015). However, while there was some preference reported by survey participants for flying in a westerly direction, there was a high incidence of jet lag being worse on return to Australia regardless of direction, indicating that workers in this sector were actually 'running on adrenaline' while travelling and paying for that physically on return to Australia.

All of this points to a lack of organisational input in the wellbeing of workers who are part of global innovation teams, particularly for the members who travel. International business travellers are a neglected but strategic human resource (Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007), and the lack of support from management for workers' work / life balance mirrored previous research in this area (Baker & Ciuk 2015; Black & Jamieson 2007), showing an opportunity for organisations to support their staff and increase not only their work / life balance, but also productivity in terms of financial and technical performance.

Having analysed the results of the survey data, this thesis now turns to a discussion of the key issues.

8. Discussion

8.1 Introduction

In this chapter the results are discussed in detail, both the qualitative and quantitative, to address the research question *'What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?'*

The aims of this study were fivefold: to conduct a literature review in the various fields that related to the research question; to construct a conceptual framework that incorporated the various elements in a globally dispersed innovation team; to conduct qualitative research using a series of interviews from a list of questions that interview subjects would elaborate on; to conduct quantitative research using an online survey in a larger population; and finally, to synthesise the qualitative and quantitative findings. These aims are now discussed in more depth.

A thorough literature review was conducted, incorporating material from innovation management, virtual team management, organisational psychology, chronobiology (the study of the circadian rhythm) and performance management. These five quite diverse disciplines were combined to form the basis of further exploration and used to develop interview and survey questions and to inform the interpretation of the results.

A conceptual framework was then constructed, examining four different forms of distance (physical, temporal, cultural and language) and their effect on globally dispersed innovation team performance. This conceptual framework was based on the relevant academic literature and incorporated the various impact-mitigating behaviours that team members engage in to minimise any negative impact of working across multiple time zones. This conceptual framework was used as the basis of coding the qualitative data, using the case study approach as outlined by Eisenhardt (1989).

Qualitative data was then obtained in a series of 28 interviews as the first phase of an exploratory mixed method approach. This allowed the qualitative data to create themes from the subject population and be tested further in the quantitative phase of the study (Creswell & Plano Clark 2011, pp. 88-9). These themes included frequently repeated quotes or statements from the interview cohort that appeared to be particularly significant. These themes were arranged using Gioia's methodology (Gioia, Corley & Hamilton 2013; Gioia & Thomas 1996), where similar themes were gathered into 'several overarching dimensions that make up the basis of the emergent framework' (Corley & Gioia 2004).

This was then followed by 153 online quantitative surveys examining themes generated from the series of interviews, as well as from the relevant academic literature. Themes that emerged particularly strongly around performance related to a sense of exhaustion, as multiple interview participants used the phrase 'running on adrenaline', and reported being exhausted on return to Australia, as well as having very long working days when they travelled. The exhaustion on return had not been encountered in the academic literature, and further exploration of this phenomenon was warranted.

The two sets of data were then united in a synthesis combining 'the power of stories and the power of numbers' (Pluye & Hong 2014) to triangulate a fuller picture of the data (Jick 1979; Olsen 2004). Themes that were generated in the qualitative phase of the study were explored further in the quantitative survey, allowing these initial findings to be generalised to a larger cohort (Creswell & Plano Clark 2011, pp. 9-10).

The theoretical implications are analysed: firstly, using the conceptual model that was created to model the various forms of distance that globally dispersed innovation teams experience within their teams between the team members. In addition, there were new data from the study that indicated that business travellers in this sector experience jet lag worse on return to Australia than flying east *versus* flying west. There is a substantial body of literature that travellers flying east experience worse jet lag than those who fly west (Diekman & Bose 2017; Facer-Childs & Brandstaetter 2015; Flower, Irvine & Folkard 2003; Lemmer *et al.* 2002; Monk *et al.* 2000; Waterhouse *et al.* 2007), but there has been relatively little research done specifically in business travellers (see section 3.5.3, particularly table 1). The conceptual model is then modified in the light of the data from the study.

The practical implications of this research included providing guidelines for those who travel, and more importantly, guidelines for the management of globally dispersed innovation teams, particularly for the members who travel frequently across multiple time zones. While there is a substantial body of literature regarding virtual team management, there is relatively little for managing virtual team members who travel frequently, and this research addresses this to some extent.

Finally, a response to the research question *'What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?*' is elaborated, looking at managing organisational performance and the effects of setting the boundaries on financial, technological and physical performance of the staff in globally dispersed innovation teams.

The first research aim, the results of the literature review in a variety of disciplines related to the research question, is now discussed.

8.2 Research Aim 1: Literature Review

The first research aim was to conduct a literature review that incorporated elements from the research question, namely, '*What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?*' To address this research question effectively, there were a total of five different research streams that needed to be examined and then brought together in a final synthesis: namely, innovation studies, the management of virtual teams, organisational psychology, chronobiology (the study of the human circadian rhythm), and finally, performance measurement and management.

One of the key findings in conducting the literature review, particularly around the area of jet lag due to business travel, was the relative lack of research conducted with business travellers. There has been quite a lot of research using healthy volunteers or athletes (see Table 1), but very little research specifically using business travellers as the research subjects. Given that business travellers make up a substantial proportion of the income for airlines' income, 'this research has overlooked an important category of international operator: the international business traveller' (Welch, Welch & Worm 2007).

Another area with little to no research to date is the benefit of flying business class on the impact of jet lag. While flying business class has been suggested as a means of ameliorating the worst effects of jet lag (Sack 2010), there is a lack of hard data to measure the actual benefit to travellers if they fly business class, or even if there is a benefit. Given that airlines typically make a large proportion of their profit from first and business class travellers (Gillen & Lall 2004), this was an unexpected finding. There has been a study on deep vein thrombosis which did not show any benefit from flying business class (Jacobson *et al.* 2003). The actual benefit of flying business class in terms of recuperating from the effects of jet lag, and the financial benefit thereby incurred by flying business class has not been quantified.

Another gap that appeared in the literature review was the lack of organisational perspective in terms of managing teams of staff who travel frequently. With regard to company policy for travel, there has been a lack of clarity (Wardman *et al.* 2015) and issues relating to compliance with company travel policy (Holma, Bask & Kauppi 2015). There have been some suggestions specifically about managing staff who travel frequently, such as offering business class flights for long distances and time off *in lieu* (Bannai & Tamakoshi 2014; Cohen, Hanna & Gössling 2018). However, a clear framework for managing staff and limiting their workload so that it is not excessive has not emerged from the literature, and the management of teams with members that travel frequently appears to be *ad hoc* and unstructured, and 'there has been a lack of systematic study and analysis of the stress, strains, and fluctuations in work performance of business travellers prior to, during, and after they return to their home offices or permanent work locations' (Ivancevich, Konopaske & Defrank 2003).

Less surprising was the fact that there has been a great deal of research conducted in the management and performance of virtual teams (Dulebohn & Hoch 2017; Gibson *et al.* 2014), especially in the context of global innovation teams (Harvey & Griffith 2007). Time zone disparity within these global virtual teams is recognised one of the key challenges in managing virtual teams (Espinosa, Nan & Carmel 2015; Gibson *et al.* 2014).

The first research aim, to develop a literature review that integrates insights on innovation, virtual teams, organisational psychology, chronobiology and performance to give insight to the effect of time zone disparity on dispersed global teams has been met. Some of the issues that were lacking in the literature have been addressed, such as specifically targeting business travellers for research and constructing a framework that organisations can employ to manage staff who travel frequent. This thesis now turns to the conceptual framework to explain the effect of time zone disparity on globally dispersed innovation team performance.

8.3 Research Aim 2: Conceptual Framework

The next research aim listed was to develop a conceptual framework that explains the effect of time zone disparity on dispersed team performance. The framework was developed in chapter 4 (see Figure 4), with the four forms of distance (or gaps) each having a potentially negative effect on globally dispersed innovation team performance, with team members utilising impact-mitigating behaviours they could exert to mollify this.

One of the key findings of this research is that the ‘impact-mitigating behaviours’ factor within the model has two distinct components: an individual component, and an organisational component. There are several actions that individual business travellers can take that can minimise the impact of travelling across multiple time zones, such as sunlight or light therapy (Lau, Lovato & Lack 2018; Lovato & Lack 2015), using melatonin (Herxheimer & Petrie 2002), wakefulness agents (Coste & Lagarde 2009; Sack 2010), hypnotic agents (Reilly, Atkinson & Budgett 2001; Sack 2009), caffeinated drinks or caffeine supplements (Coste & Lagarde 2009), dietary modifications (Ruscitto & Ogden 2017), exercise (Atkinson *et al.* 2007). adjusting the schedule to the new time zone before travelling (Revell & Eastman 2005), or remaining on the schedule of the time zone of origin for very short journeys (Arendt 2009).

However, the temporal organisational approaches to managing teams that span multiple time zones, particularly business travellers, was a key deficiency both in the relevant academic literature and in the conceptual model created. Three distinct types of organisational behaviour in relation to teams who spanned multiple time zones were identified in the qualitative phase of the study, which were labelled *laissez-faire*, ‘concentrate the pain’ and ‘set the boundaries’. Most company policy is focussed on the class of flight that business travellers undertake, with financial pressure for business travellers to fly economy (Mason 2000, 2001, 2002, 2005). However, this policy is not evidence-based, as there is currently nothing in the scientific literature that demonstrates a benefit of flying business class for jet lag, and flying business class has not even been shown to be beneficial for deep vein thrombosis (Jacobson *et al.* 2003), a key safety concern for frequent flyers.

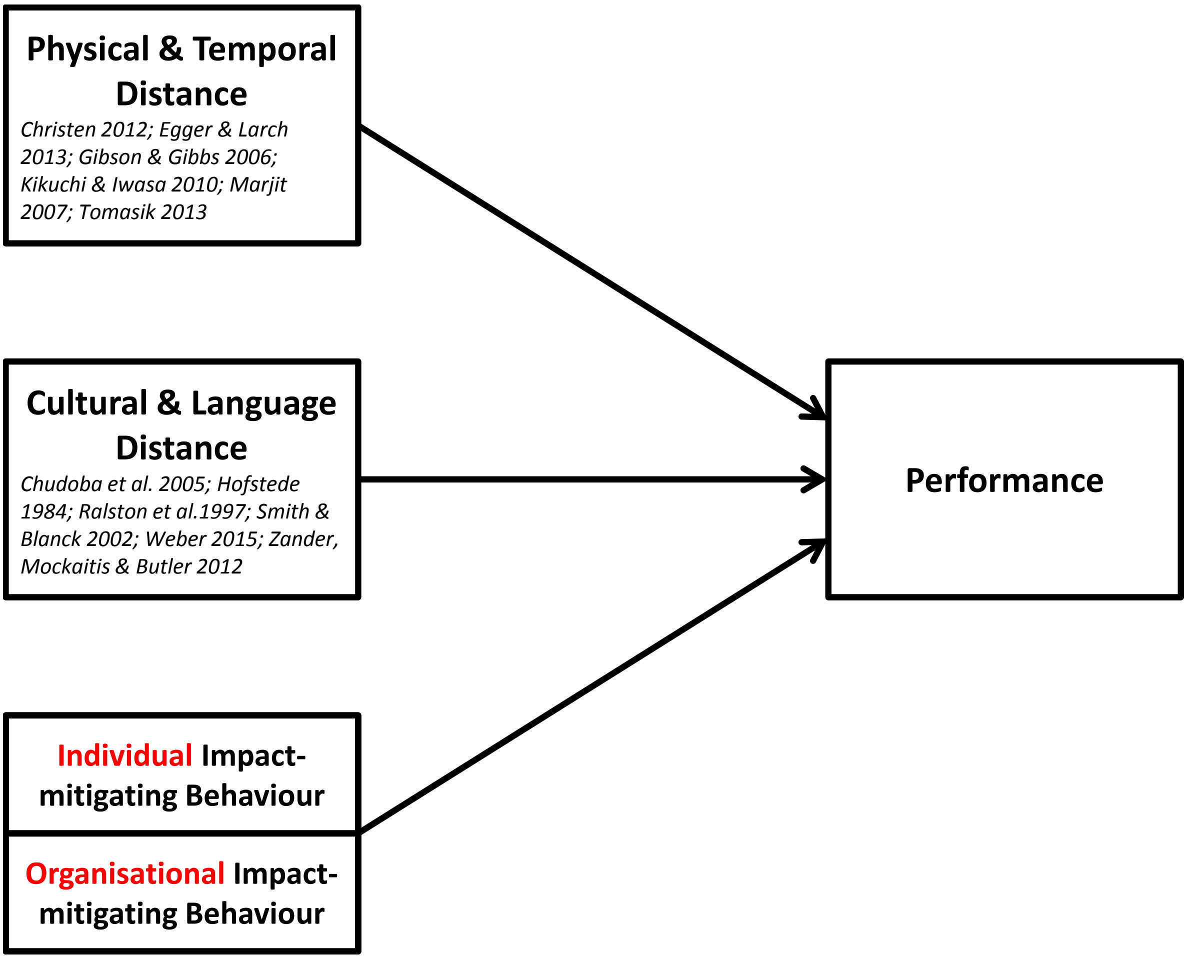
With the *laissez-faire* management approach, employees are simply left to their own devices in terms of travel and jet lag management. One of the possible factors identified by interview participants was a lack of appreciation of the burden of travelling long distances: ‘unless people do it, as in senior management, unless they’ve done it, then they're not going to necessarily appreciate what’s required to get things done’ (19 16:29).

This division between senior management who do not commonly travel internationally and a cohort of staff who do travel frequently is an example of another management approach that we have labelled ‘concentrate the pain’. With this strategy, people are hired to travel more frequently. For example, a business development manager who was specifically appointed to travel (25 07:46) or project leaders who took on a high travel burden (12 02:29). It is known that some people experience less jet lag than others (Ruscitto & Ellis 2007; Waterhouse *et al.* 2007), so that there may be some self-selection for business travellers in terms of roles involving a large amount of international travel.

The final approach is deemed ‘set the boundaries’, in which organisations set limits on the burdens that business travellers experience. There were a small number of cases from the qualitative data where boundaries were very clearly set, such as the interview subject who insisted his staff fly business class (01 15:15), and one interview subject who had a questionnaire for the company's staff to ensure that they did not work too many hours (22 12:47). The academic literature refers to companies that offer upgraded flights for long distances of more than five hours or time off *in lieu* (Bannai & Tamakoshi 2014; Cohen, Hanna & Gössling 2018) However, while company policy may have specified an upgraded flight for a long distance above a certain number of hours, this company policy was not always followed, which is exemplified in the case of one interview subject who annually flew to the United States, in which the company policy for upgraded flights was specifically disregarded (09 15:22), reflecting the issues around compliance with company travel policies (Holma, Bask & Kauppi 2015). Given that international business travellers are a neglected resource in terms of skills and knowledge transfer (Welch, Welch & Worm 2007), it would seem prudent to offer stronger support to these workers to enhance their performance.

The modified conceptual framework for team distances and their effects on team performance is given below.

Figure 16: Modified Model of Team Distance



A finding that was not unexpected was that temporal and physical gaps caused difficulties for globally dispersed innovation teams. Temporal distance, as measured in time zone differences, were a challenge for many interview subjects: having to work at odd hours because of time zone differences (09 01:40; 18 08:10; 21 05:00; 24 05:59), with the odd hours being accepted as ' just part of the deal: if you… live in Australia,… it's going to be what suits the head office' (21 04:04), and one interview subject found the inability to phone colleagues due to time zone differences restricting (06 03:30). There was also a large amount of international travel reported for Australian workers in this sector (08 16:20; 19 13:30; 21 03:19; 25 17:00), with one interview subject stating 'Australia's at the wrong place at the wrong time for just about anywhere in the world' (19 13:30). Impaired performance associated with time zone differences and temporal distance is consistent with the literature on global innovation virtual teams (Gibson *et al.* 2014).

Physical distance, measured by distance in kilometres, was also a challenge for team members is globally dispersed innovation teams. As stated in the academic literature, physical proximity is a positive factor in scientific collaborations (Abramovsky & Simpson 2011; Kabo *et al.* 2014), and lack of proximity between team members is associated with poorer performance (Gibson *et al.* 2014). Proximity was identified as being important to one subject, particularly in the early phases of research (02 11:44).

Also, the strong influence of cultural and language issues in team performance was an expected finding. Several interview subjects reported difficulties with working with cultures very different from their own, particularly Asian cultures, where one interview subject preferred 'working with similar Western cultures, it's far easier in a business sense than working with, say, an Asian culture or a Middle Eastern culture' (02 12:24), and cultural differences within the team led to poor performance (02 13:00; 07 03:15, 08:00). Generally, there was a marked preference for working with colleagues in the United States and Europe, which were temporally and physically much more distant, but culturally and linguistically much more aligned. The difficulties associated with cultural differences in globally dispersed innovation teams mapped very closely with the cultural differences measured in Hofstede (1984) and quantified by Malik (2013).

Similarly, the linguistic differences as quantified by using Levenshtein distances (Petroni & Serva 2010; Wichmann *et al.* 2010) successfully predicted the barriers that language differences contributed to the challenges in communication for globally dispersed innovation teams.

The model was modified by dividing the impact-mitigating behaviour into two categories, individual and organisational, with the other four components, temporal, physical, cultural and language gaps all having a negative impact on team performance. The literature has focused primarily on the impact of individual impact-mitigating behaviour in terms of jet lag references, with only limited examination of the organisational impact-mitigating behaviours that can be achieved such as a travel policy (Mäkelä & Kinnunen 2018), despite international business travellers being a valuable resource to a company (Welch, Welch & Worm 2007) and the very real possibility of a lack of duty of care by companies for their employees who frequently travel (Black & Jamieson 2007).

The data taken from the qualitative phase of the study, the 28 interviews, is now analysed.

8.4 Research Aim 3: Synthesis of Qualitative and Quantitative Results

Having examined the qualitative interview data and the quantitative survey data separately, the two sets of results are now combined to bring together 'the power of stories and the power of numbers' (Pluye & Hong 2014), allowing the initial findings to be explored and generalised (Creswell & Plano Clark 2011, pp. 9-10), and synergistically combining the strengths of both methods of research using data from both data sets to triangulate the data to obtain a clearer picture, combining methodologies to examine one phenomenon (Hussein 2009; Jick 1979).

The phrase 'running on adrenaline' was particularly illuminating in this context, as it was volunteered by several interview subjects, painting a picture of absolute exhaustion for this cohort. The reasons for this exhaustion in members of global innovation teams in the

Australian biotechnology industry appeared to be threefold, and all related to being part of global innovation teams that spanned multiple time zones: working long hours, working at odd hours, and jet lag from travel. These three factors are now examined individually.

Long hours were reported in this cohort, particularly when traveling due to the need to be checking emails (13 01:16), socialising with clients (19 09:13), and working up to fifteen hours *per* day (16 07:13). Long working hours have been defined as working form more than 61 hours per week (Brett & Stroh 2003), although in some working environments the 60-hour workweek 'is now practically considered part-time', with workers putting in up to 120 hours per week (Hewlett & Luce 2006).

Working long hours results in significant disruption to family life (Espino *et al.* 2002; Harrington 2001; Hewlett & Luce 2006), with international business travel particularly disruptive (Saarenpää 2016). Long hours can also be detrimental to the health not only of the business traveller, but also their spouse (Dimberg *et al.* 2002). The dangers to health of working long hours are substantial and have been demonstrated, with an increased rate of mortality associated with working long hours (Goh *et al.* 2015). The risk of cardiovascular disease is significant for people with long working hours (Bannai & Tamakoshi 2014; Spurgeon, Harrington & Cooper 1997; van der Hulst 2003). In a meta-analysis of more than half a million people, working more than 55 hours per week was associated with an increase in risk of coronary heart disease and stroke (Kivimäki *et al.* 2015). There is a large number of negative health consequences associated with working long hours, including mental health issues (Bannai & Tamakoshi 2014; Ganster, Rosen & Fisher 2018; Spurgeon, Harrington & Cooper 1997), gastrointestinal disorders and musculoskeletal problems (Spurgeon, Harrington & Cooper 1997) and diabetes mellitus (Bannai & Tamakoshi 2014; van der Hulst 2003).

Similarly, disturbances to sleep and associated fatigue is linked to working long hours (Åkerstedt *et al.* 2002), with possible resulting negative effect on performance, as cognitive function is impaired (Bannai & Tamakoshi 2014). Fatigue from long working hours are likely to result in poor physical health (Goh, Pfeffer & Zenios 2015; van der Hulst 2003) and can result in severe negative health outcomes (Pfeffer 2018), as overall mortality rate is increased with working long hours (Bannai & Tamakoshi 2014; Goh *et al.* 2015). Something noted from the data was that hours tended to be longer when travelling, thus the fatigue from working long hours coincided with fatigue associated with jet lag, potentially leading to even poorer outcomes, and contributing to the tiredness experienced by many of those surveyed in the study. For one interview subject the exhaustion associated with frequent travel meant that they were waking up in hotels not knowing where they were (07 12:00), and most survey respondents reported that team members were often exhausted when they travel.

The subjects surveyed and interviewed in this study were generally working long hours, with most teams surveyed having members who worked more than 60 hours per week (see section 7.5 for data). This quantitative data presented in Figure 15 aligns with the qualitative data, where a high number of interview subjects spontaneously generated the phrase 'running on adrenaline', and strongly suggests that there are negative health issues that this cohort is likely to experience due to their long working hours in global innovation teams.

Employees working long hours can be a symptom of organisational culture dysfunction (Balthazard, Cooke & Potter 2006), and long schedules may even be a 'contest' among staff to prove their commitment (Berdahl *et al.* 2018). Given the serious and potentially fatal effects of employees working overly long hours, it would appear companies have a duty of care to their staff to intervene to ensure they do not work such long hours that it potentially impairs their health (Black & Jamieson 2007). It is reasonable to ask why companies do not intervene, as 'all Australian jurisdictions have duty of care legislation which requires an employer to be mindful (and more) of an employee's health and safety' (Black & Jamieson 2007). Working long hours has a very negative effect on work / life balance, as there is 'spillover' into the free time of the employee, particularly at the higher levels of management (White *et al.* 2003), and supporting work / life balance decreases burnout in staff (Pariser 2017) and turnover (Beauregard & Henry 2009). Certainly 'work / life balance was something of a challenge' for one interview subject (27 07:46) with a lack of organisational input to support these workers as discussed in section 7.9. Organisational support is something potentially useful for international business travellers, who are a valuable resource for their companies (Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007).

Employees working odd hours, outside the usual nine-to-five business hours, was also a significant issue for this cohort. Even for workers in global innovation teams who do not travel, have teleconferences late in the evening, during the night or early in the morning, which can result in social jet lag (Reid & Abbott 2015; Wittmann *et al.* 2006), with similar symptoms to those who fly due to the disruption of the circadian rhythm. Working outside normal hours is likely to result in exhaustion (Nurmi 2011), which was a prominent complaint by both interview subjects and survey participants. This is particularly challenging for workers in global teams in the Australian context, as most international teams have members that are a long way from Australia in terms of time zone differences (Gilding 2008). Communication technology is a double-edged sword in this aspect; while it can enable business travellers to connect with their families at home (Ladkin *et al.* 2016) and potentially reduce the need for travel (Espinosa, Nan & Carmel 2015), the distinction between work life and home life can be blurred (Köffer *et al.* 2015). The 24/7 connectivity that modern communication technology offers leads to significant challenges to employees' work / life balance, with staff being asked to choose 'to prioritize their jobs ahead of other parts of their lives: their role as parents (actual or anticipated), their personal needs, and even their health' (Reid & Ramarajan 2016), and work now having 'boundarylessness', with staff being able to work from anywhere at any time, with no clear delineation between work life and home life (Kossek 2016). In the interviews an evening call at 9 p.m. was difficult for one subject who was a morning person, which interfered with their personal and family life (18 18:30), and another who started their day at three o'clock in the morning to attend meetings being 'driven largely by adrenaline' (25 06:46). The financial performance of organisations was enhanced when staff looked after their medical needs and when a 'set the boundaries' management approach, which involves limiting the impact of working in teams that span multiple time zones, was implemented in the workplace (section 7.5.2), so it would appear that it is in organisations' best interests financially to support their staff who work in globally dispersed teams across multiple time zones.

Jet lag was a significant challenge to this cohort. The medical literature has reported a high level of direction asymmetry with jet lag, as eastbound flights are likely to cause more severe jet lag than westbound flights (Flower, Irvine & Folkard 2003; Lemmer *et al.* 2002; Monk *et al.* 2000; Waterhouse *et al.* 2007), although there are individual differences with 'morning people' experiencing the reverse (Diekman & Bose 2017; Facer-Childs & Brandstaetter 2015; Sack 2010). However, the phenomenon of people experiencing worse jet lag on return from a business trip, regardless of the direction travelled, has not been encountered in the literature. The rating for worse jet lag on return (5.09 on a scale from 1 to 7) was higher than the preference of flying west to east (4.58 on the same scale). The experience of this cohort included a lot of working while fatigued and jet lagged: ‘the body is tired, but you just kind of work through it, that’s been my experience. You’re running on adrenaline a lot of the time.’ (06 05:03), and certainly aligned with the experience of ‘conducting business in a cloud of caffeinated jet lag’ (Czeisler & Fryer 2006) as reported in the literature. The severity of the jet lag on return was, however, not anticipated, with travellers being on a ‘high’ when they travel and ‘turn off the turbos’ when they return (15 08:59), trying to ‘store up all that need for sleep’ then ‘trying to catch it up’ on return to Australia (25 07:29).

One of the most striking findings was the lack of organisational input to support staff who work in innovation teams that span multiple time zones, despite being a strategic resource for their organisations (Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007), with organisations not even recognising them as a valuable resource. Several interview subjects felt that their efforts were not appreciated by upper management, who didn’t share the travel burden: ‘unless people do it, as in senior management, unless they’ve done it, then they're not going to necessarily appreciate what’s required to get things done’ (19 16:29). This would explain the lack of management support to assist workers with their work / life balance, because workers at that level were expected to ‘look after themselves’ (Black & Jamieson 2007). Because of this lack of organisational input and the moderating influence it has on performance, the conceptual framework that was postulated in section 4.5 (see figure 4) has been modified to incorporate a separate organisational input as well as an individual one (see section 8.3, figure 16). This organisational input not only has a positive effect on employee wellbeing but has also a positive effect on financial performance (section 7.5.2).

In summary, triangulating the data to combine the qualitative and quantitative data in this study (Jick 1979), which allowed this study to blend ‘the power of stories and the power of numbers’ (Pluye & Hong 2014). Both sets of data pointed to a sense of exhaustion, with global innovation team members ‘running on adrenaline’, with a lack of organisational support. This aligned with the academic literature, where business travellers have been reported to be living out of a suitcase ‘conducting business in a cloud of caffeinated jet lag’ (Czeisler & Fryer 2006). Innovation is global, and given the importance of working internationally in innovation teams (Cano-Kollmann, Hannigan & Mudambi 2018), particularly in the Australian context (Gilding 2008), it is important to support international business travellers (Mäkelä & Kinnunen 2018), who are a greatly undervalued resource for firms (Black & Jamieson 2007; Welch, Welch & Worm 2007). There are strategies that organisations can employ to support staff in global innovation teams, and these opportunities for organisational input with practical steps are discussed in detail in section 8.8. The theoretical implications of the results of the study are now discussed.

8.5 Theoretical Implications

8.7.1 Introduction

This section addresses the theoretical implications of this study and is divided into two main sections: the first section addresses the streams of literature that were discussed in chapter 3, and the second section discusses the conceptual framework and the modification to it in the light of the data from this study.

The streams of literature from chapter 3 (innovation management, virtual team management, organisational psychology, chronobiology and performance management) are now discussed, commencing with innovation management.

8.7.2 Literature Streams Addressed

Innovation is global, and firms need to be internationalised to be innovative (Cano-Kollmann, Hannigan & Mudambi 2018; Kafouros *et al.* 2008). However, the resulting virtual team formation can have a negative impact on creativity (Martins & Shalley 2011). Biotechnology is dependent on and driven by innovation (Fetterhoff & Voelkel 2006; Gilsing & Nooteboom 2006; Hall & Bagchi-Sen 2002; Rothaermel & Hess 2007; Wu 2013), making the study of innovation management of vital importance in this field.

In the Australian context, biotechnology companies typically work with American or other international partners (Gilding 2008; Guan, J & Chen, Z 2012), but the distance (both physical and temporal) puts Australian companies at a disadvantage (Gittelman 2007), resulting in Australian biotechnology companies being relatively small (Standing, Standing & Lin 2008). The Australian biotechnology industry is therefore an excellent case study to examine the effect of temporal distance on an industry that is highly innovative.

Virtual team management has a wealth of literature, with a strong focus on negotiating the geographical distances within a virtual team (Hoegl, Ernst & Proserpio 2007; Purvanova & Kenda 2018), the configuration of the virtual team (O'Leary & Mortensen 2010; Polzer *et al.* 2006; Somech & Drach-Zahavy 2013), cultural differences within the team (Daim *et al.* 2012; Staples & Zhao 2006; Vignovic & Thompson 2010), and language difficulties within the team (Ferreira, de Lima & da Costa 2012). Temporal distances as measured in time zone differences also add to the challenge of working in virtual teams, with team members working long working days and working at odd hours outside of normal business hours due to asynchronous communication (Chudoba *et al.* 2005; Nurmi 2011). These observations from the literature were reflected in this cohort, as the temporal distances within the virtual team increased the demands on the team (Kanthak & Hertel 2016). However, to a limited extent this increased demand on members of global teams is offset by virtual teams being able to employ a 'follow the sun' method of working (Carmel, Espinosa & Dubinsky 2010; Dulebohn & Hoch 2017), in which work can be undertaken on a continuous 24-hour basis.

While the geographical, configurational, cultural, language and temporal aspects of virtual team management have been discussed, there has been limited attention paid to the needs of the staff who travel between the hubs of a virtual team (Welch, Welch & Worm 2007). Face-to-face meetings are important for virtual teams (Kelley 2001; Siebdrat, Hoegl & Ernst 2009), which results in some team members who travel long distances internationally across multiple time zones experiencing jet lag (Cohen & Gössling 2015), often resulting in a negative impact on performance (Czeisler & Fryer 2006). The guidelines for management of virtual teams do not focus on the needs of the team members who travel frequently and there is generally a lack of organisational support for international business travellers (Black & Jamieson 2007; Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007) which this study seeks to address. A key finding of this study is that the needs of business travellers appears to be different to those of other travellers, with business travellers frequently being exhausted on their return journey, in this instance, to Australia.

Another key finding of this study is the impact of organisational psychology and culture on working in global innovation teams across multiple time zones. Organisational culture describes an organisation's behaviour, beliefs and values (Kummerow, Ying & Kirby 2014, p. 5; Zander, Jonsen & Mockaitis 2016), and a dysfunctional organisational culture can have a negative effect of employees' wellbeing (Balthazard, Cooke & Potter 2006). There were several examples of poor organisational culture given by interview subjects in the qualitative phase of the study, such as when the company policy for travelling in business class for travelling long distances internationally was overridden by a manager (09 15:29), the interview subject who felt that senior management did not appreciate what was required for their role in terms of the long hours (19 16:29), and the interview subject who worked for 15 hours a day when they travelled for business (16 07:02). All these incidents had a negative impact on the motivation of the interview subject who reported them. There were also a few examples of a supportive organisational culture from the interview subjects, such as management questioning staff on their working hours (22 12:47), flying staff internationally business class (01 15:15; 03 05:44; 06 07:45; 10 08:01; 15 01:20; 27 01:44) or allowing flexible working hours (02 10:00; 04, notes; 05 06:29; 08 06:30; 09 02:45; 12 12:15; 14 06:15; 23 11:12; 24 06:25), although these were not as frequent as they could have been. The importance of the organisational input resulted in a substantial change in the conceptual model presented earlier (see section 8.3), with impact mitigating behaviour being employed at both an individual level and at an organisational level.

Long hours appeared to be a substantial problem with this cohort, with multiple interview subjects using the phrase ‘running on adrenaline’ (02 18:15; 06 05:15; 10 11:45; 15 08:30; 17 12:43; 24 11:35), echoing the work of Black and Jamieson (2007) with a high amount of long hours worked, with the health challenges associated with long hours are severe and potentially fatal (Pfeffer 2018; Sparks *et al.* 1997; Spurgeon, Harrington & Cooper 1997). Clearly there is room for greater organisational support for this cohort, and this organisational input is distinct from the individual input in terms of impact-mitigating behaviours to offset the negative effects of temporal and other forms of distance in globally dispersed innovation teams.

Turning to chronobiology, the literature regarding jet lag states that flying westward is less likely to cause severe jet lag than flying eastward (Flower, Irvine & Folkard 2003; Lemmer *et al.* 2002; Monk *et al.* 2000; Waterhouse *et al.* 2007), although there is some individual variation (Diekman & Bose 2017; Facer-Childs & Brandstaetter 2015; Sack 2010). While there was some slight preference for flying westward by survey participants, there was a higher rating of experiencing worse jet lag on return to Australia by survey participants (see discussion in section 8.6). This unique finding that has been not noted in the relevant existing literature. However, in jet lag research there has been relatively little research with business travellers (see table 1 in section 3.5.3), and the finding that return flights pose more of a challenge in terms of jet lag than outbound flights indicates that the needs of business travellers are distinct from those of other travellers. The long hours and lack of support from management that many business travellers experience (Baker & Ciuk 2015; Black & Jamieson 2007; Czeisler & Fryer 2006; Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007) and the long hours reported by some interview subjects such as 15 hours per day (16 07:02) point to a culture of exhaustion and even a 'macho' culture where working long hours is a badge of honour (Berdahl *et al.* 2018). The common experience of business travellers in this cohort of being exhausted and jet lagged on return to Australia challenges the traditional model of jet lag with directional asymmetry, and indicates that business travellers have different needs and behave differently when they travel.

Performance was self-reported, as this is a difficult industry to measure and a previous study in the Canadian biotechnology industry used self-reporting questionnaires (Hall & Bagchi-Sen 2002). Three aspects of performance were measured: financial, technological and physical performance. While the physical performance of team members was unsurprisingly connected to how well they managed the physical symptoms of jet lag, both the technological and financial performance of teams were also linked to the wellbeing of staff in these global innovation teams. Given that jet lag and the associated sleep loss has a negative effect on cognitive function (Åkerstedt 2007; DeSanctis 2017; Goel *et al.* 2009; Harrison & Horne 1999; Kelley, Evans & Kelley 2018; Killgore & Weber 2014), there are implications for the practical management of globally dispersed innovation teams, which are discussed in detail in section 8.8.

This chapter now discusses the conceptual framework that was developed in chapter 4 and its relation to the results found in the study.

8.7.3 Conceptual Framework

This section now addresses the conceptual framework that was postulated in chapter 4. Four types of distance were recognised from the literature as having an impact on globally dispersed innovation teams: physical, temporal, cultural and language distances. All four forms of distance were acknowledged by the interview subjects as having a negative impact, with physical distance being referred to by multiple subjects with the phrase 'the tyranny of distance' (01 01:44; 22 16:17, 17:31). The conceptual framework acknowledged these four forms of distance, with two pairs of more closely related distances, namely physical and temporal (Christen 2017; Tomasik 2013), and cultural and language (Weber 2015). These four forms of distance all have a negative impact on performance that is offset by mitigating behaviours. What this study demonstrated, however, is that mitigating behaviours have two components: at the individual level as well as the organisational level. For staff who travel frequently, there appears to be a lack of organisational intervention and support for the 'very frequent flyers' (Black & Jamieson 2007) who frequently travel internationally (Baker & Ciuk 2015).

A striking finding from the data was regarding the individual component of impact mitigating behaviours, which was that many were ineffective or marginally effective at best, particularly for jet lag (see section 7.7). Compare the poor uptake of light therapy (a score of 3.02 on a scale of 1 = never, 7 = always), despite the strong evidence for its usefulness in jet lag (Lahti *et al.* 2007; Sack 2010; Samuels 2012; Waterhouse *et al.* 2007). This indicates a potential benefit of education for staff in these teams who fly across multiple time zones frequently, possibly as a form of organisational support.

Finally, there appears to a very high incidence of exhaustion in this cohort, with multiple interview subjects generating the phrase 'running on adrenaline' or the word 'adrenaline' (02 18:15; 06 05:15; 10 11:45; 15 08:30; 17 11:47, 12:43; 24 11:35; 25 06:46), and a higher incidence of jet lag on return to Australia than there was a preference of flying westward over eastward. While there is very strong evidence that flying westward cause fewer jet lag symptoms than the same distance eastward (Flower, Irvine & Folkard 2003; Lemmer *et al.* 2002; Monk *et al.* 2000; Waterhouse *et al.* 2007), there was nothing in the academic literature to suggest that jet lag symptoms would be worse on return, indicating that the needs of business travellers are different from those of other travellers, and are particularly prone to exhaustion, again suggesting the need for some organisational support in mitigating the effects of working across multiple time zones. Exhaustion has a negative impact not only on physical performance (which would be as expected), but potentially on financial performance (see discussion in section 7.5.2), as staff who looked after their medical issues strongly correlated with positive financial performance.

To summarise the discussion of the conceptual framework, three things stand out: the need for a much higher level of organisational input to support staff (which was a component that modified the conceptual model), the often-ineffective impact mitigation employed by individual team members, and the high rate of exhaustion in this cohort.

The practical implications of this study, including the measures that organisations can take to support their staff who work in innovation teams that span multiple time zones, particularly ones who travel frequently, is discussed in detail in the next section.

8.6 Practical Implications

There are several steps that organisations can take to support their staff who work in globally dispersed innovation teams that span multiple time zones. In relation to the three management strategies previously discussed in section 6.5, two of these are selected for further discussion: the 'concentrate the pain' approach, and 'set the boundaries', as the *laissez-faire* approach is most commonly employed and offers no real benefit to staff in global innovation teams.

The 'concentrate the pain' strategy can be used in two places. Firstly, it can be used to select staff who frequently travel, which was reported by one interview subject who hired a business development manager 'whose job is to travel' (25 07:49). This can be beneficial, as it is known that some people experience less jet lag than others (Arendt 2009; Ruscitto & Ellis 2007; Waterhouse *et al.* 2007), and can be used for staff to select themselves who are willing and able to travel with minimal impact.

This 'concentrate the pain' methodology can also be applied to staff who typically remain on the ground in Australia. For partnerships with the United States or Canada teleconferences are typically in the morning due to the time zones (Australian time), so it could be prudent to delegating liaising with North American partners to 'morning people', while for partnerships with Europe teleconferences are typically in the evening so team members who liaise with their European counterparts could be delegated to ‘evening people’.

The ‘set the boundaries’ strategy takes a different approach, with proactive methods to ensure work / life balance such as providing flexibility and taking time zone differences into account when managing staff (Kossek 2016), preventing the exhaustion that so often accompanies business travel (Czeisler & Fryer 2006).

An effective way to ‘set the boundaries’ is by monitoring working hours so that staff do not work excessive hours. Given the serious mental and physical health challenges associated with long working hours (Bannai & Tamakoshi 2014; Goh *et al.* 2015), this could potentially be an important intervention. One interview subject reported a questionnaire tracking working hours (22 12:47) to ensure working hours were not overly high.

This is particularly important for workers who are travelling, as they are coping with an exhausting schedule as well as possibly the effects of jet lag, and one interview subject reported working for 15 hours a day while travelling (16 07:02). Having a team member who has responsibilities delegated to them could also be useful, rather than have the business traveller check emails for hours on end while travelling (13 01:16; 16 07:13; 19 09:13). For those who travel frequently and spend a lot of time away from home, time off *in lieu* would support staff working odd or long hours (Black & Jamieson 2007; Cohen, Hanna & Gössling 2018), as well as flexible working hours (Kossek 2016; ter Hoeven & van Zoonen 2015), provided that the company is supportive of flexible hours (Topcic, Baum & Kabst 2016).

While there is a lack of data on the benefit of flying business class, with only the lack of effect of flying business class on the development of deep vein thrombosis researched (Jacobson *et al.* 2003), flying business class for long flights was certainly appreciated by those interviewed, who said that they could relax or sleep better flying business class. One interview subject, however, routinely flew from Australia to London in economy, and questioned this as false economy: ‘if it’s really that valuable to get me over, is it worth having me over and in the right frame of mind? In which case, paying that extra four thousand dollars or whatever it is – would that make that difference that means I actually can function there right away’ (15 18:53).

As discussed earlier, there is directional asymmetry with jet lag, with most travellers finding westward travel easier than eastward travel in terms of jet lag (Arendt 2009; Ruscitto & Ellis 2007; Waterhouse *et al.* 2007). However, there is genetic variation (Arendt 2009) in this response to jet lag, with ‘morning people’ experiencing less jet lag flying eastward (Diekman & Bose 2017; Facer-Childs & Brandstaetter 2015; Sack 2010). As many interview subjects spoke of combining multiple destinations when they travel for cost savings (refer to section 6.4), for travellers flying around the world combining multiple destinations. For example, for a business traveller who needed to fly to destinations in the United States and Europe who experiences less jet lag flying westward, there could be a substantial improvement in performance if they flew from Australia to Europe first, and then on to the United States.

Another method of supporting staff in global teams is ensuring that exercise is available. This could include installing a gymnasium at a workplace (Baicker, Cutler & Song 2010), or allowing team members who travel to stay in hotels with a gymnasium (Welch & Worm 2006). In the words of one interview subject, ‘all the bad habits come out when you travel’ (13 10:55), and challenges with maintaining an exercise routine while travelling for business has been reported in the literature (Black & Jamieson 2007), as well as difficulty maintaining a healthy lifestyle (Chen 2017). The benefits of exercise are not only for physical wellbeing (which showed a significant positive correlation in this study with financial performance, see section 7.5.2), but a lack of exercise has been linked to depression (Rimer *et al.* 2012).

Finally, an expression of acknowledgment and appreciation for staff who work in globally dispersed innovation teams for their efforts, particularly for the frequently long hours or time worked late at night or early in the morning, especially when travelling. Recognition of employees' efforts increases their motivation (Brun & Dugas 2008), a result that has been borne out experimentally (Bradler *et al.* 2016; Grant & Gino 2010). One interview subject stated that as senior management did not undertake the frequent travel across multiple time zones, they were likely to understand the workload and what was needed to get things done and felt underappreciated, typically working late most days (19 16:29).

There are benefits for organisations that proactively intervene to support their staff who work in globally dispersed innovation teams. The financial performance of those surveyed was significantly and positively associated with members who took care of themselves, and there is less likelihood of burnout, loss of productivity or even significant health challenges to employees who are supported by their organisation. Importantly, there is a duty of care of organisations to their staff, and given the significant potential health risks associated with very long hours that are commonplace in this cohort, it would seem prudent for organisations to support their staff from a duty of care perspective (Black & Jamieson 2007).

Having synthesised the results from the qualitative and quantitative segments of the study, this thesis now returns to the research question

8.7 Response to the Research Question

Having examined the practical implications of this study and steps that organisations can take to support members of globally dispersed innovation teams in their work, this thesis now revisits the research question of the study:

- *What is the effect of time zone disparity on the performance of dispersed teams in a global innovation context where physical gaps, cultural gaps and language gaps are prominent?*

With the research question examining the temporal gaps in globally dispersed innovation teams, this discussion now examines how organisational performance can be managed to maximise the financial and technological performance of the organisation, as well as the physical performance of the members of the global innovation team. Therefore, this thesis now addresses the effect of organisations 'setting the boundaries' in performance, with financial, technological and physical performance being discussed separately.

Regarding financial performance, the 'set the boundaries' management strategy had a statistically significant ($p < 0.05$) positive impact on the financial performance of organisations. Similarly, team members who took a medical approach by taking melatonin or other prescribed medication to manage jet lag had a very statistically significant ($p < 0.01$) impact on their organisation's financial performance. Mitigating the effect of temporal gaps, particularly for frequent international travellers, improves the financial performance of the organisation, whereas if there is a *laissez-faire* approach within the organisation, or team members do not address their medical needs when they fly, temporal gaps within innovation teams have a negative impact on the organisation's financial performance.

Turning to the technological performance of the final product, again a medical approach had a positive effect on performance, this time with the 'tips and tricks' variable where team members use light therapy (including sunlight), diet, exercise and hydration ($p < 0.01$), and the 'circadian adjustments' variable where team members use light therapy or adjust their daily pattern and schedule ($p < 0.01$). Again, having healthy and functioning team members had a positive outcome for performance, in this case technological, as addressing the symptoms of jet lag can minimise the cognitive impairment that jet lag causes (Åkerstedt 2007; Cho 2001; Coste & Lagarde 2009). The 'cultural gaps' in the research question, however, had a statistically significant ($p < 0.01$) negative effect on technological performance, possibly due to poor communication across cultures. Several interview subjects noted projects that failed due to cross-cultural misunderstandings in China (07 03:18), India (07 08:59), and Japan (02 13:00). These cultural gaps were a possible confounding factor, and interview subjects generally indicated a strong preference to work with more similar, Western cultures (02 12:24).

Unsurprisingly, physical performance was very heavily linked with multiple medical interventions, including 'medical approach' which involved the use of melatonin or other drugs ($p < 0.01$), 'time management' in which team members flew in early ($p < 0.01$), 'circadian adjustments' in which members used light therapy or adjusted their daily schedules ($p < 0.05$), and to some extent 'tips and tricks' in which team members use light therapy (including sunlight) diet, exercise and hydration ($p < 0.10$). Surprisingly however, the 'cultural gaps' in the research question had a strongly significant negative effect ($p < 0.01$) on physical performance, which was not anticipated, and it is difficult to speculate on the reason for this finding.

Overall, however, team members whose medical needs for travel are addressed by various means have a positive effect on the financial and technological performance of the organisation and their own physical performance. Having evaluated the research question in the light of the study results, the discussion of the results of this study are now summarised.

8.8 Summary

This section summarises the key points in the discussion in this chapter, outlining key findings.

Firstly, jet lag is generally poorly managed in this cohort, and this reflects the reported experience in the literature of business travellers 'conducting business in a cloud of caffeinated jet lag' (Czeisler & Fryer 2006). There was often ineffective impact mitigation by individual travellers, who had poor uptake of effective treatments for jet lag such as light therapy (Lahti *et al.* 2007; Sack 2010; Samuels 2012; Waterhouse *et al.* 2007), and higher uptake of less effective or problematic treatments for jet lag such as exercise (Atkinson *et al.* 2007) or caffeine (Burke *et al.* 2015).

The directional component of jet lag, where flying west has less impact than flying east (Flower, Irvine & Folkard 2003; Lemmer *et al.* 2002; Monk *et al.* 2000; Waterhouse *et al.* 2007) was less prominent than a higher incidence of jet lag on the return flight (see section 7.8), which was not expected from the literature. Both interview subjects and survey participants reported working long hours, particularly while travelling, with one interview subject reporting 15 hours per day while travelling (16 07:02), and many survey subjects working 60 or more hours a week (see section 7.6). There was a high incidence of exhaustion reported by interview subjects, which was borne out in the survey, when most of the survey respondents gave a positive response to the question 'team members are often exhausted when they travel' (section 7.7).

This exhaustion comes at a cost to productivity. There was a cost to physical performance, which correlated well with team members using a medical approach, managing their time, and taking steps to ameliorate the symptoms of jet lag (section 7.5.4), which was not an unexpected finding. However, this exhaustion also has a cost on technological performance, where team members who ameliorated their jet lag symptoms had better technology outcomes (section 7.5.3), and financial performance, where team members who used a medical approach and working in a 'set the boundaries' organisational context provided better financial outcomes (section 7.5.2).

Study participants often reported a lack of understanding or empathy from senior management, with one interview subject saying that senior managers who didn't work the long and odd hours would not appreciate what was needed to get their job done (19 16:29). This lack of empathy or understanding could be the cause of the lack of organisational input found in this study and in the literature, despite the legal requirements of duty of care in Australian jurisdictions (Black & Jamieson 2007).

Employee performance can be improved, and the best way to do this is through organisational input as described in detail in section 8.8. This would be beneficial not only for the employees' wellbeing, but also the financial bottom line for the company. Certainly, this study showed evidence of toxic organisational cultures where staff are exhausted, are 'running on adrenaline' and feel the need to 'soldier on'. Companies with frequently travelling staff have 'a highly competitive, continuously demanding corporate culture which informally, yet increasingly and incessantly, squeezes travellers to do more work to the inevitable detriment of their personal lives. Indeed, one very senior executive expressed the opinion that the limits of human capacity of this type of work had been met, leading to the burn out and high turnover of staff’ (Black & Jamieson 2007).

Having summarised the discussion of the data, this thesis now addresses the conclusions to the study.

9. Conclusions

9.1 Introduction

This chapter examines the conclusions of the study, with focus on the limitations and strengths of the study while suggesting avenues for future research in this area.

9.2 Strengths of the Study

The study has several strengths, making it different from previous studies that have been conducted in this area, which are outlined below.

Firstly, in terms of population numbers, there were relatively large numbers of both interview subjects (28 subjects) and survey participants (153 participants), and few studies in the effect of temporal disparity on globally dispersed innovation teams have been conducted on this scale. Research has been done in international business travellers including a study of ten business travellers based in Australia and Denmark (Welch, Welch & Worm 2007), and 232 Finnish international business travellers (Mäkelä & Kinnunen 2018), and the research in this study builds on this earlier work.

Secondly, the study consisted of two phases, a qualitative interview stage and a quantitative online survey stage. The benefits of using mixed methods in social science research include a better triangulation of the data, minimising the weaknesses of each method, and benefiting from each method's strengths (Hussein 2009), using qualitative data to explore the themes that are then measured in the quantitative phase of the study (Creswell & Plano Clark 2011, pp. 88-9), enriching the data.

Thirdly, the study was specifically conducted in business people, which is particularly relevant in terms of the effects of jet lag. While there have been many studies on either athletes or healthy volunteers, there have been relatively few studies of business travellers (see Table 1).

While business travellers are recognised as an important resource for firms (Welch, Welch & Worm 2007), and a large component of airlines' income is from business class passengers (Gillen & Lall 2004), this appears to be a segment that has been relatively overlooked in terms of research. Given the high amount of exhaustion already reported in this cohort (Czeisler & Fryer 2006), it would seem appropriate to examine business travellers' experiences in more depth, particularly in the Australian context, where business travellers face longer travel times and cross a greater number of time zones due to the 'tyranny of distance' (Gilding 2008).

Finally, this study has brought together a variety of disciplines, and has been informed by academic literature from innovation management, virtual team management, organisational psychology and chronobiology. These disciplines have been combined in an approach where the study methodology and findings have been informed by a combination of these approaches.

Having examined the strengths of this study, the limitations of the study are now addressed.

9.3 Limitations of the Study

While the study was comprehensive and had quite a few strengths, there were several limitations to the study, which are now discussed.

Firstly, the study subjects were all taken from one nation, Australia. Australian subjects typically partner with more distant nations and travel longer distances than their American or European counterparts, so that the impact of time zone differences and jet lag may also be greater. It could be useful to conduct a similar study with American, Asian or European participants to see if the effect of temporal distance on performance for those working in globally dispersed innovations teams was as severe, or whether it was moderated by relatively smaller temporal distances and fewer team members with high temporal distance.

Secondly, the study participants were all from a single industry, the biotechnology sector. The organisational culture reported in this sector may be very different from other sectors where there are teams that are temporally dispersed, such as information technology or finance. Other industries may have more generous allowances in terms of time off *in lieu*, flying business class or other means of supporting employees.

Thirdly, there were also some differences within the biotechnology sector, as it is a very broad category with many applications in the area of life science (EuropaBio 2013; Kafarski 2012). In addition, there is a variety of company sizes, from the largest multinational pharmaceutical operations to a multitude of very small start-ups, that are more likely to experience financial pressures and cash flow turbulence (Grohn *et al.* 2015). The variety within this industry may mean that some subsectors, or different types of biotech companies, will have very different company cultures that may not necessarily be applicable across the sector.

Fourthly, this study specifically targeted innovation teams. There are many globally dispersed teams that do not necessarily work on innovative products, nor need to, but their workflow and output are relatively routine and predictable. There is therefore no impact on innovation, but there may be other effects of temporal distance on productivity that this study would not necessarily accurately evaluate.

Fifthly, performance, the key output in the conceptual model created and pivotal to the measurement of the study was self-reported by both interview subjects and survey participants. Harder, more quantifiable data (such as profit, sales, etc.) would have been difficult to measure in the current study, as the innovations in this sector are typically very high-risk and long-term, with profit not always readily available, particularly in the early stages of development. The study in this industry therefore had to accommodate the lack of financial data because of the many long-term high-risk studies, and therefore could only use self-reported data. If a similar study was conducted in other industries with lower risk and a shorter time frame to market (such as the financial sector), quantifiable financial data could potentially be obtained.

Lastly, there was a degree of gender imbalance in the interview phase of the data, with only one third of the interview subjects being female, and the data for sex/gender was not collected in the survey phase of the study.

Having discussed the limitations of this study, directions for future research are now suggested.

9.4 Suggestions for Future Research

Several avenues for further research present themselves for further exploration. Firstly, the impact of temporal disparity on team members of globally dispersed innovation teams can be examined using workers from nations other than Australia. The Australian context was useful because so many workers in these teams are a long way from their international colleagues, dealing with the 'tyranny of distance' (Gilding 2008), and short-term international travel from Australia has more than doubled in the decade 2002 – 2012 (Pike 2016). While Australia is relatively isolated internationally (Gilding 2008), international travel rates globally are increasing rapidly, more than doubling in the past two decades (The World Bank 2017). Even within the United States jet lag has been noted for sports teams travelling domestically (Recht, Lew & Schwartz 1995; Song, Severini & Allada 2017). Impairment of performance from jet lag is likely to be noticed in other contexts such as for American business travellers (Czeisler

& Fryer 2006) or European business travellers (Mäkelä & Kinnunen 2018; Welch, Welch & Worm 2007).

Secondly, other industries that have innovation teams that span multiple time zones could be used as the study context. The organisational culture findings in this study may be specific to biotechnology, and other industries such as information technology or finance and banking could provide different results.

The information technology industry is negatively affected by time zone differences in its global teams (Nguyen-Duc, Cruzes & Conradi 2015), although it benefits greatly from being able to use a 'follow the sun' approach (Carmel, Espinosa & Dubinsky 2010; Dulebohn & Hoch 2017), in which work is scheduled on a continuous 24-hour basis. Similarly, the international banking industry is adversely affected by time zone differences (Wójcik 2010), and studies on the effect of time zone differences within international teams in this sector may yield different results.

Thirdly, the study targeted teams that were working on innovative products. Globally dispersed teams that are not innovative were omitted from the study and removing the innovation management component from the study may also provide different results if the teams are working on well-established products that are not innovative. Time zone differences are a factor that has a negative impact on virtual team performance, regardless of the nature of the virtual team (Chudoba *et al.* 2005; Maznevski & Chudoba 2000), and the 'follow the sun' method of working for virtual teams is applicable for all virtual teams, including those that are performing routine maintenance tasks (Carmel, Espinosa & Dubinsky 2010; Dulebohn & Hoch 2017).

Fourthly, there was a lack of study of the benefits of flying business class, particularly in jet lag management. While flying business class has been examined in terms of deep vein thrombosis (Jacobson *et al.* 2003), there's a lack of definite evidence for its recommendation in jet lag other than anecdotal support (Sack 2010). There is evidence of business class not being effective to prevent deep vein thrombosis (Scurr *et al.* 2001); however, while airlines receive a high proportion of their income form business travel (Gillen & Lall 2004), there is a paucity of data on the measured benefits of flying business class, particularly in areas of most importance to business travellers such as alertness, cognitive function and sleep patterns (Czeisler & Fryer 2006).

Finally, the benefit of interventions for business travellers at the corporate level could be explored, particularly with interventions from human resources. There are several approaches that organisations can implement, using the 'concentrate the pain' or 'set the boundaries' strategies. An assessment of performance and staff satisfaction can be assessed after a program designed to minimise the impact of working in teams across multiple time zones, and supporting international business travellers in terms of workload and pressure with human resources policies would enhance performance for these workers (Mäkelä & Kinnunen 2018).

9.5 Summary

A key finding of this study was how frequently jet lag is poorly managed by employees who travel frequently. As frequent travel and the resulting jet lag cannot be avoided, the impact of jet lag must be managed, preferably by using evidence-based methods. Given that the cohort is typically more scientifically literate than most, being employed in the biotechnology sector, it appeared that the organisational and industry culture of ‘running on adrenaline’ and ‘pushing through’ overrode the use of scientifically validated methods for alleviating jet lag.

A striking feature of conducting research in this area was the lack of data for business travellers and jet lag. While there is a wealth of literature on the effects of jet lag athletes and healthy volunteers, the cohort of business travellers appears to be a population that is frequently overlooked. Business travellers are more likely to fly business class, have shorter journeys, and have heavy workloads with long hours while travelling.

Similarly, there was very little data on the benefit of flying business class, particularly for jet lag. Given that airlines receive a large proportion of their income from business class travellers (Gillen & Lall 2004), it would be useful to have more data in this area, which could potentially be used to justify the excess cost of flying business class. While the literature on the management of virtual teams is well developed, and it is recognised that virtual teams need team members to travel, this specific aspect of the management of virtual teams has not received a great deal of attention.

The key finding in the study is that organisations have several different approaches to managing teams, which were identified as ‘*laissez-faire*’, ‘concentrate the pain’ and ‘set the boundaries’. Organisations most commonly take the *laissez-faire* approach to managing these teams, which means that employees are left to their own devices in terms of managing their workload and productivity. This finding echoes a previous study of 25 frequent business travellers, there the researchers did not find any evidence of intervention for these workers because of ‘the prevailing ideology that workers at this executive level can look after themselves’ (Black & Jamieson 2007). There is much more that can be done by companies proactively to manage these teams, which can not only increase productivity but also work / life balance for the team members. While some interventions are expensive (such as long-distance business class travel), some are relatively inexpensive to implement. Given the distance Australia is from its business partners (Gilding 2008), this has a high degree of relevance for Australian companies, and multinational companies with significant operations in Australia.

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Appendix A: Participant Information and Consent Form

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

PARTICIPANT INFORMATION

Project Title:

The Effect of Time Zone Disparity on the Performance of Dispersed Innovation Teams

Investigators:

Stephen Jasper, Masters by Research Candidate, Graduate School of Business and Law, RMIT University, Melbourne, Australia. Email: stephen.jasper@rmit.edu.au tel: 03 9925 8356

Professor Mark Leenders, Professor of Marketing, Graduate School of Business and Law, RMIT University, Melbourne, Australia. Email: mark.leenders@rmit.edu.au tel: 03 9925 1582

Dr. Tim O'Shannassy, Senior Lecturer, Graduate School of Business and Law, RMIT University, Melbourne, Australia. Email: tim.oshannassy@rmit.edu.au tel: 03 9928 0111

Dear Participant,

You are invited to participate in a research project being conducted by RMIT University. This information sheet provides you with an overview of the research project in plain language. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate. If you have any questions about the project, please ask one of the investigators.

Who is involved in this research project? Why is it being conducted?

This research is being conducted by Mr Stephen Jasper, as a part of his Masters of Research at the Graduate School of Business and Law, RMIT University. Professor Mark Leenders is the senior supervisor and Dr. Tim O'Shannassy is the second supervisor for this project. The aim of this research is to explore and detail the effect of time zone disparity on the performance of dispersed innovation teams, using the Australian biotechnology sector as the industry setting. This research project has been approved by the RMIT Human Research Ethics Committee.

Why have you been approached?

This research is focused on employees in the Australian biotechnology sector working in dispersed innovation teams with time zone disparity within the teams. You have been approached with this invitation because you have been identified as fitting within this criterion. Identifying you or your organisation as a potential participant has been facilitated through AusBiotech, other industry associations, or other research participants.

What is the project about? What are the questions being addressed?

The primary research question being addressed is 'what is the effect of time zone disparity on the performance of dispersed innovation teams?' The individual interviews are stage one of this research project. They are intended to explore the significant issues and key factors affecting staff working in dispersed innovation teams with time zone disparity of three hours or more working in the Australian biotechnology sector. The individual interviews will include 6 participants from the Australian biotechnology sector; it is expected that half of these participants will be male and the other half female. Participants will be employees working in the Australian biotechnology sector, who are part or have recently been part of dispersed innovation teams with time zone disparity (≥ 3 hours).

If I agree to participate, what will I be required to do?

You (the participant) will be asked to provide information in response to open-ended questions about your experiences in dispersed innovation teams with time zone disparity, within the context of the Australian biotechnology sector. Each interview will take approximately one hour, and be audio-recorded with the consent of participants. Participants will be informed about the reasons for recording and may opt to switch the recorder off at any time.

What are the possible risks or disadvantages?

There are no perceived risks outside your normal day-to-day activities. The only disadvantage is a loss of time but your participation will make a valuable contribution to this research. If you are unduly concerned about your responses to any of the interview questions or if you find participation in the project distressing, you should contact any one of the above investigators as soon as convenient. We will discuss your concerns with you confidentially and suggest appropriate follow-up, if necessary. If you wish to make a complaint about your participation in this project please see the complaints box below and please follow the complaints procedure.

What are the benefits associated with participation?

It is likely that there will be no direct benefit to you as a participant apart from a free electronic report briefly summarising research findings upon request and after completion of the project. However your participation in this research will likely benefit biotechnology companies in Australia and other countries, as well as other industries that have dispersed innovation teams across a variety of time zones. This is because this research intends to provide outcomes that will assist the future management of dispersed innovation teams, as well as contribute to theory in this area.

What will happen to the information I provide?

Confidentiality and privacy will be strictly maintained during all stages of the research. No information you provide will be passed on to your organisation. Only codes or numbers will be used to represent participants and their organisations in reporting results, which will be made public in the forms of thesis and papers published in journals or conferences. Any information that you provide can be disclosed only if (1) it is to protect you or others from harm, (2) a court order is produced, or (3) you provide the researchers with written permission. All electronic data will be stored on password secured university network systems. Hard copy data will be archived in the locked filing cabinet and locked office at Graduate School of Business and Law at RMIT University. The research data will be kept securely at RMIT for 5 years after publication, before being destroyed. Please note that due to the nature of data collection we will be requesting written informed consent from you.

What are my rights as a participant?

Your participation in this research is completely voluntary. There are no penalties if you decide not to participate. As a participant, you have:

- The right to withdraw from participation at any time;
- The right to have any unprocessed data withdrawn and destroyed, provided it can be reliably identified, and provided that so doing does not increase the risk for the participant;
- The right to be de-identified in any photographs intended for public publication, before the point of publication; and,
- The right to have to have any questions answered at any time.

Whom should I contact if I have any questions?

If you have any questions or enquires regarding this project or your participation you can contact Stephen Jasper, email: stephen.jasper@rmit.edu.au, or Professor Mark Leenders, tel: 03 9925 1582, email: mark.leenders@rmit.edu.au, or Dr. Tim O'Shannassy, tel: 03 9928 0111, email: tim.oshannassy@rmit.edu.au

Yours sincerely,

Stephen Jasper	Professor Mark Leenders	Dr. Tim O'Shannassy
Masters by Research candidate	Professor of Marketing	Senior Lecturer
RMIT University	RMIT University	RMIT University
stephen.jasper @rmit.edu.au	mark.leenders @rmit.edu.au	tim.oshannassy @rmit.edu.au

If you have any concerns about your participation in this project, which you do not wish to discuss with the researchers, then you can contact the Ethics Officer, Research Integrity, Governance and Systems, RMIT University, GPO Box 2476V VIC 3001. Tel: (03) 9925 2251 or email human.ethics@rmit.edu.au

CONSENT

1. I have had the project explained to me, and I have read the information sheet

2. I agree to participate in the research project as described

3. I agree**:**
   - to be interviewed and/or complete a questionnaire

- that my voice will be audio recorded

4. I acknowledge that:
   a) I understand that my participation is voluntary and that I am free to withdraw from the project at any time and to withdraw any unprocessed data previously supplied (unless follow-up is needed for safety).
   b) The project is for the purpose of research. It may not be of direct benefit to me.
   c) The privacy of the personal information I provide will be safeguarded and only disclosed where I have consented to the disclosure or as required by law.
   d) The security of the research data will be protected during and after completion of the study. The data collected during the study may be published, and a report of the project outcomes will be provided to me upon request. Any information which will identify me will not be used.

Participant's Consent

Participant ______________________________ Date: ________________

(Signature)

Appendix B: Sample Interview Questions

These questions were a checklist that was used to generate interview questions, although not all questions were used (for example, if a team only had UK / US / Australian members, questions about language were irrelevant). This list evolved over the interview process, and the questions not always asked in order. The following was a set list of questions before each interview:

Pre-interview

- Check if it is a good time
- No commercial-in-confidence information is required, so no company names, people names, or data are required or requested (any accidentally made will be redacted from the transcript).
- Can decline to answer any question or terminate the interview at any time
- All material is totally confidential, with steps in place to maintain privacy explained
- No reference to illegal activities to be made in interview

Project

- In thinking about a recent project, which countries were involved?
- Was the project a success?

Travel / Jet lag

- Who in the team travels? Does the interviewee travel? Are there people from one level of management, or one country who travels more than others?
- How much do Australians travel *versus* overseas colleagues?
- How much travel was done? How often?
- Do you experience jet lag much at all?
- Do you find flying east or flying west worse for jet lag?
- Are you more of a morning person, or an evening person? (academic literature suggests a link)
- Do you experience jet lag going to your destination, or is it worse on return?

- Do you or your team members fly business class?
- What are the benefits, if any, of meeting face-to-face?

Language

- Were there any language barriers?

Communication

- What communication technology was used in the project?
- In conference calls, videoconferences, etc., were people direct? Was this directness appreciated?

Culture

- Were there any cultural misunderstandings in the project?
- Were Americans in the team US-centric in terms of time zones? (This issue was raised spontaneously by several interview subjects.)

Temporal

- Were there any logistic issues in the project?
- Were there any missed deadlines due to Australia being a day ahead?
- When were the meeting times for various members of the team?
- Was there flexibility? If you were on a late-night call, could you go into work late the following day, or leave work early if needed?
- How was the work / life balance for team members in the project?

Final words

After all questions asked, does the interview subject have any additional final comments to make about working in a team distributed across multiple time zones?

Appendix C: Online Survey Questions

Survey questionnaire

Thank you for agreeing to take part in this survey on time zone differences and performance of innovation teams. This survey only takes take 15 minutes to complete. There are no right or wrong answers and no personal information is requested. All answers will be kept in the strictest confidence. Think of your last innovation project that you worked on as part of a team that spanned multiple time zones and answer the questions below. Team members do not all need to be part of the same organisation.

1.1 Please select which sector of biotechnology your team is/was working in:

- Pharmaceutical ◯
- Medical devices ◯
- Agriculture ◯
- Food technology ◯
- Digital technology ◯
- Energy ◯
- Other (please specify) ◯ [ ]

1.2 Please select which stage of development your team is/was working in:

- Proof of concept ◯
- Early clinical / early development ◯
- Late clinical / late development ◯
- Marketed products ◯

These questions are about your team, and the nature of the collaboration. <u>Think about your most recent team.</u>

1.3 What was the average size of this team (number of people) over the duration of this project?

[*members*]

1.4 How long did the project team last?

[*years*]

These questions are about the difference in time zones within your team, and the degree of time zone separation within the team. <u>Think about your most recent team.</u>

2.1 Which country are you based in? [ ]

2.2 In terms of members within your team, approximately how many are from each region?

<u>Asia-Pacific</u>

Australia (except WA) [ ]

Japan, South Korea [ ]

China, Singapore, Western Australia [ ]

<u>Europe</u>

UK, Ireland [ ]

Continental Europe (France, Germany, etc.) [ ]

<u>North America</u>

US / Canada East Coast [ ]

US / Canada Central Zone [ ]

US / Canada Mountain Zone [ ]

US / Canada West Coast [ ]

<u>Other</u> (please specify) [ ] [ ]

These questions are about the type of innovation your team was working on. Think about your most recent team.

		Strongly disagree						Strongly agree
3.1	The level of innovation of the project is very high	①	②	③	④	⑤	⑥	⑦
3.2	In our project team analytics are important	①	②	③	④	⑤	⑥	⑦
3.3	Our work depends greatly on customer input	①	②	③	④	⑤	⑥	⑦
3.4	The work we do involves a lot of creative problem solving	①	②	③	④	⑤	⑥	⑦
3.5	Our work requires interdisciplinary collaboration	①	②	③	④	⑤	⑥	⑦

These questions are about the spread of your team across different time zones. Think about your most recent team.

		Strongly disagree						Strongly agree
4.1	Team members are spread across multiple time zones around the world	①	②	③	④	⑤	⑥	⑦
4.2	It is difficult to arrange a meeting time with overseas team members	①	②	③	④	⑤	⑥	⑦
4.3	Team members take time zones into account when they talk to other team members	①	②	③	④	⑤	⑥	⑦
4.4	Team members often contact other team members in different time zones	①	②	③	④	⑤	⑥	⑦

These questions are about behaviours and processes used to mitigate the effect of time zones on team members. Think about your most recent team.

		Strongly disagree						Strongly agree
5.1	There is someone who covers a team member's work when they travel	①	②	③	④	⑤	⑥	⑦
5.2	Team members are expected to 'push through' fatigue and jet lag	①	②	③	④	⑤	⑥	⑦
5.3	There are processes in place to ensure team members do not work too many hours	①	②	③	④	⑤	⑥	⑦
5.4	Team members work longer hours when they travel	①	②	③	④	⑤	⑥	⑦
5.5	Team members work more than 60 hours per week	①	②	③	④	⑤	⑥	⑦
5.6	Team members are flexible with their working hours	①	②	③	④	⑤	⑥	⑦
5.7	Team members often fly outside working hours	①	②	③	④	⑤	⑥	⑦
5.8	Team members often Skype outside working hours	①	②	③	④	⑤	⑥	⑦

5.9 There is a select group of team members who travel a lot across time zones	①	②	③	④	⑤	⑥	⑦
5.10 In my team, Australians are more prone to fly overseas than other nationalities	①	②	③	④	⑤	⑥	⑦
5.11 Some people in my team are specifically hired to undertake a lot of travel	①	②	③	④	⑤	⑥	⑦
5.12 In my team, there is an employer policy that caps flying days for specific members	①	②	③	④	⑤	⑥	⑦
5.13 There are members of my team that cover the travel burden	①	②	③	④	⑤	⑥	⑦

These questions are regarding flights that team members have used to travel, both domestically and internationally. <u>Think about your most recent team.</u>

	Strongly disagree						**Strongly agree**
6.1 Executive members of my team often fly business class	①	②	③	④	⑤	⑥	⑦
6.2 The majority of team members fly business class internationally	①	②	③	④	⑤	⑥	⑦
6.3 The majority of team members fly business class domestically	①	②	③	④	⑤	⑥	⑦
6.4 The majority of my team have frequent flyer programs	①	②	③	④	⑤	⑥	⑦

These questions are about the measures individual team members take to mitigate the impact of travelling across multiple time zones. <u>Think about your most recent team.</u>

	Strongly disagree						**Strongly agree**
7.1 Team members use caffeine when they travel	①	②	③	④	⑤	⑥	⑦
7.2 Team members avoid caffeine when they travel	①	②	③	④	⑤	⑥	⑦
7.3 Team members avoid drinking alcohol when they travel	①	②	③	④	⑤	⑥	⑦
7.4 Team members take wakefulness agents when they travel	①	②	③	④	⑤	⑥	⑦
7.5 Team members use sunlight when they travel	①	②	③	④	⑤	⑥	⑦
7.6 Team members use light therapy when they travel	①	②	③	④	⑤	⑥	⑦
7.7 Team members take prescribed medication (not including melatonin) for jet lag when they travel	①	②	③	④	⑤	⑥	⑦
7.8 Team members take melatonin when they travel	①	②	③	④	⑤	⑥	⑦
7.9 Team members exercise to prevent jet lag	①	②	③	④	⑤	⑥	⑦
7.10 Team members go shopping when they travel	①	②	③	④	⑤	⑥	⑦

7.11	Team members wait until evening before they sleep	①	②	③	④	⑤	⑥	⑦
7.12	Team members take naps when they travel	①	②	③	④	⑤	⑥	⑦
7.13	Team members drink plenty of water when they fly	①	②	③	④	⑤	⑥	⑦
7.14	Before team members travel across time zones they adjust the time they wake up and go to sleep	①	②	③	④	⑤	⑥	⑦
7.15	Team members use ear plugs or noise cancelling headphones when they fly	①	②	③	④	⑤	⑥	⑦
7.16	Team members adjust their schedule before leaving on an overseas business trip	①	②	③	④	⑤	⑥	⑦
7.17	Team members maintain a healthy diet when they travel	①	②	③	④	⑤	⑥	⑦
7.18	If a business trip is short, team members do not bother adjusting to the new time zone	①	②	③	④	⑤	⑥	⑦
7.19	It is difficult for members of my team to attend morning meetings when travelling	①	②	③	④	⑤	⑥	⑦
7.20	Team members use daylight to adjust to different time zones	①	②	③	④	⑤	⑥	⑦
7.21	Team members like to fly in early to destinations	①	②	③	④	⑤	⑥	⑦
7.22	Team members adjust their daily pattern to the new time zone before they fly	①	②	③	④	⑤	⑥	⑦
7.23	Team members complain a lot about travel	①	②	③	④	⑤	⑥	⑦
7.24	Team members go shopping to alleviate jet lag	①	②	③	④	⑤	⑥	⑦
7.25	Team members can fend off jet lag until they return	①	②	③	④	⑤	⑥	⑦
7.26	Jet lag is worse for team members when they return home	①	②	③	④	⑤	⑥	⑦
7.27	Team members prefer flying west than east	①	②	③	④	⑤	⑥	⑦

These questions are about work-life balance and stress factors for team members. <u>Think about your most recent team.</u>

		Strongly disagree						**Strongly agree**
8.1	In my team, family lives suffer as a result of their work	①	②	③	④	⑤	⑥	⑦
8.2	In my team, social lives suffer as a result of their work	①	②	③	④	⑤	⑥	⑦
8.3	Team members work their home lives around their work lives	①	②	③	④	⑤	⑥	⑦
8.4	Members of my team are often stressed	①	②	③	④	⑤	⑥	⑦

These questions are about team dynamics. <u>Think about your most recent team.</u>

		Strongly disagree						Strongly agree
9.1	In my team there was a friendly attitude among members	①	②	③	④	⑤	⑥	⑦
9.2	In my team, there was open communication of relevant information between team members	①	②	③	④	⑤	⑥	⑦
9.3	When disagreements arose in my team, we were able to resolve them quickly	①	②	③	④	⑤	⑥	⑦
9.4	In my team, there were excellent relationships between team members	①	②	③	④	⑤	⑥	⑦
9.5	Information exchange between the team and the larger organisation was adequate	①	②	③	④	⑤	⑥	⑦
9.6	My team had access to world-class knowledge and resources	①	②	③	④	⑤	⑥	⑦
9.7	My team had access to world-class market intelligence	①	②	③	④	⑤	⑥	⑦
9.8	My team had excellent marketing capabilities	①	②	③	④	⑤	⑥	⑦
9.9	My team used state of the art information and communication technology	①	②	③	④	⑤	⑥	⑦
9.10	My team was well funded	①	②	③	④	⑤	⑥	⑦
9.11	My team was well balanced in terms of capabilities	①	②	③	④	⑤	⑥	⑦
9.12	My team had full support from senior management	①	②	③	④	⑤	⑥	⑦
9.13	Responsibilities were clear and well defined in my team	①	②	③	④	⑤	⑥	⑦

These questions are about the experience of jet lag for members of the team. <u>Think about your most recent team.</u>

		Strongly disagree						Strongly agree
10.1	Team members are often exhausted when they travel	①	②	③	④	⑤	⑥	⑦
10.2	Team members experience insomnia during and after they travel	①	②	③	④	⑤	⑥	⑦
10.3	Team members often experience daytime sleepiness when they travel	①	②	③	④	⑤	⑥	⑦
10.4	Team members experience impaired mood when they travel	①	②	③	④	⑤	⑥	⑦
10.5	Team members are unable to think clearly for a day or two after travel	①	②	③	④	⑤	⑥	⑦
10.6	Team members have trouble with memory when they travel	①	②	③	④	⑤	⑥	⑦
10.7	Team members experience light-headedness or dizziness when they travel	①	②	③	④	⑤	⑥	⑦

10.8	Team members are drowsy during the day when travelling for business	①	②	③	④	⑤	⑥	⑦
10.9	Team members have trouble concentrating or thinking clearly when they travel	①	②	③	④	⑤	⑥	⑦

These questions are about the performance (or expected performance) of the product or service that the team developed. Think about your most recent team and compare it with similar sized projects.

If the product(s) has not yet been launched, give your best estimate of expected market performance.

		Strongly disagree						**Strongly agree**
11.1	The technology my team developed is very functional	①	②	③	④	⑤	⑥	⑦
11.2	The product(s) the team developed provides us with a sustainable competitive advantage	①	②	③	④	⑤	⑥	⑦
11.3	The product(s) the team developed met our cost goals	①	②	③	④	⑤	⑥	⑦
11.4	The product(s) the team developed was launched on time	①	②	③	④	⑤	⑥	⑦
11.5	The product(s) the team developed performs to specifications	①	②	③	④	⑤	⑥	⑦
11.6	The product(s) the team developed met its deadlines and critical milestones	①	②	③	④	⑤	⑥	⑦
11.7	The product(s) the team developed met quality guidelines	①	②	③	④	⑤	⑥	⑦
11.8	The product(s) the team developed got to market quickly	①	②	③	④	⑤	⑥	⑦
11.9	Management views our product as a success	①	②	③	④	⑤	⑥	⑦
11.10	Our team satisfaction level is high	①	②	③	④	⑤	⑥	⑦
11.11	The team's product met its sales volume goals	①	②	③	④	⑤	⑥	⑦
11.12	The team has been recognised as being very successful	①	②	③	④	⑤	⑥	⑦
11.13	Our team is likely to hit its long term profit goals	①	②	③	④	⑤	⑥	⑦
11.14	Our team is likely to hit its revenue targets	①	②	③	④	⑤	⑥	⑦
11.15	The products or services my team developed are well received by customers	①	②	③	④	⑤	⑥	⑦
11.16	The products or services my team developed achieve high customer satisfaction	①	②	③	④	⑤	⑥	⑦
11.17	The products or services my team developed exceed revenue targets	①	②	③	④	⑤	⑥	⑦
11.18	The products and services my team developed are very profitable	①	②	③	④	⑤	⑥	⑦

11.19	The products or services my team developed meet market share goals	①	②	③	④	⑤	⑥	⑦
11.20	The products and services my team developed met its year 1 market share goal	①	②	③	④	⑤	⑥	⑦
11.21	The products and services my team developed meet its sales volume goal	①	②	③	④	⑤	⑥	⑦
11.22	The customers that bought our team's product are loyal customers	①	②	③	④	⑤	⑥	⑦
11.23	Our product(s) the team developed reached break-even earlier than expected	①	②	③	④	⑤	⑥	⑦
11.24	The products and services my team developed are highly successful in the market	①	②	③	④	⑤	⑥	⑦
11.25	The products and services my team developed met *all* its market share goals	①	②	③	④	⑤	⑥	⑦
11.26	The products and services my team developed met *all* their technology goals	①	②	③	④	⑤	⑥	⑦

These questions are about geographical, cultural and language differences within the team. Think about your most recent team.

		Strongly disagree						**Strongly agree**
12.1	The majority of the team's travel is within the same or adjacent time zones	①	②	③	④	⑤	⑥	⑦
12.2	In my team, most of the flying is fly north-south	①	②	③	④	⑤	⑥	⑦
12.3	Physical distance is a bigger problems than time zones	①	②	③	④	⑤	⑥	⑦
12.4	Members of my team find some cultures difficult to deal with for business	①	②	③	④	⑤	⑥	⑦
12.5	Team members in different cultures can be 'hard to read'	①	②	③	④	⑤	⑥	⑦
12.6	The majority of my team find communication with other cultures difficult	①	②	③	④	⑤	⑥	⑦
12.7	Cultural differences are a big problem in my team	①	②	③	④	⑤	⑥	⑦
12.8	Our team uses English as the default language	①	②	③	④	⑤	⑥	⑦
12.9	Sometimes it can be difficult to understand some team members' accents	①	②	③	④	⑤	⑥	⑦
12.10	In team meetings there are people who have English as a second language present	①	②	③	④	⑤	⑥	⑦

*Thank you for completing this survey, your time completing this is greatly appreciated. Please be assured that all material from this survey will remain completely confidential. If you have any questions or concerns regarding this survey, please contact **Stephen Jasper** at RMIT University at stephen.jasper@rmit.edu.au.*